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THE BOTANICAL GARDEN AT RIO DE JANEIRO

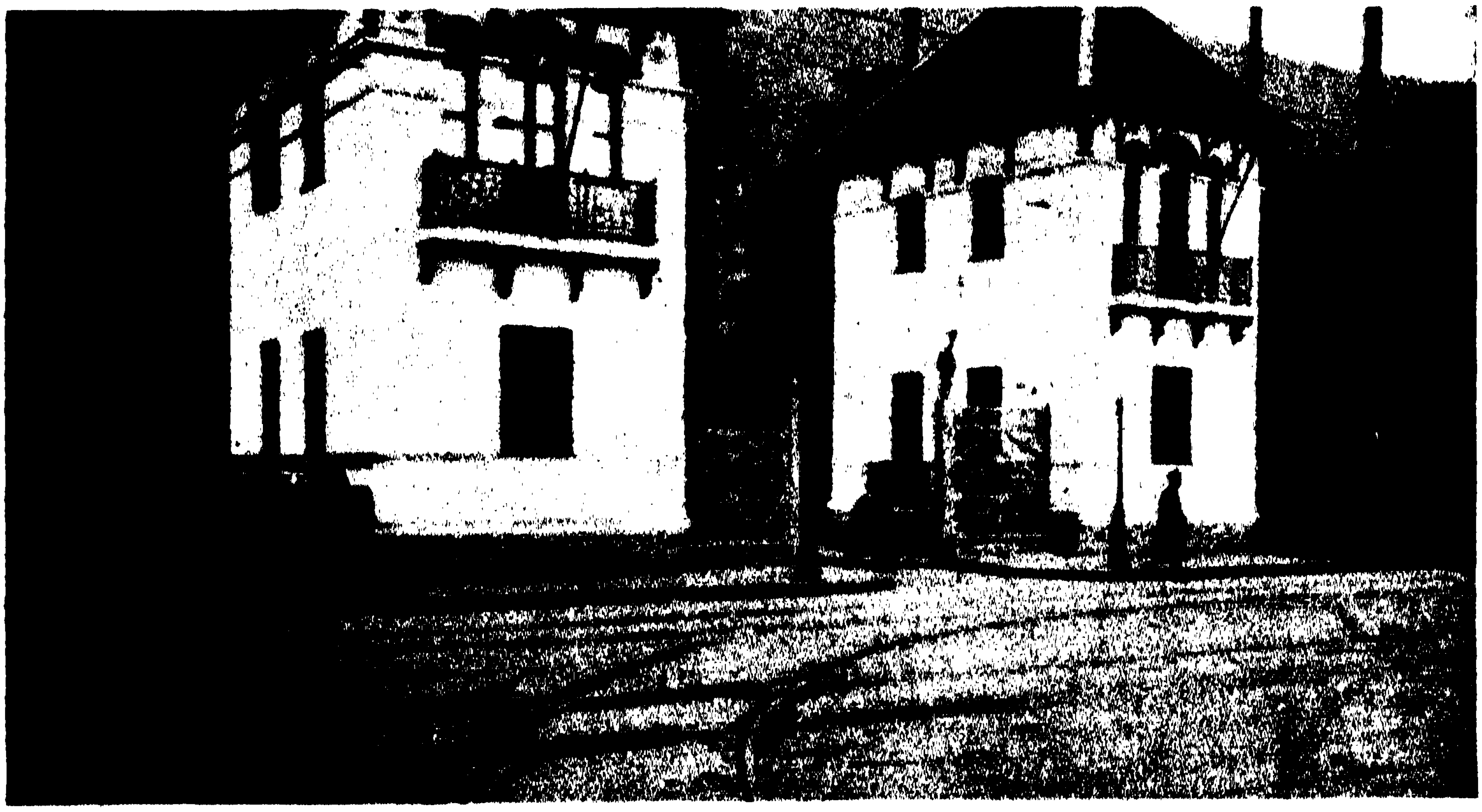
By Dr. F. LAMSON-SCRIBNER

WASHINGTON, D. C.

AMONG the many and altogether charming lures of the Capital City of Brazil is its Botanical Garden—Jardim Botanico do Instituto de Biologica Vegetal—located amidst wonderfully picturesque surroundings in a region where it is always summer. All the warmer countries of the world have contributed to its collections of living plants, interesting alike to the botanist and the traveler. The wonderful flora of Brazil is richly represented with the characteristic species of the Valley of the Amazon predominating.

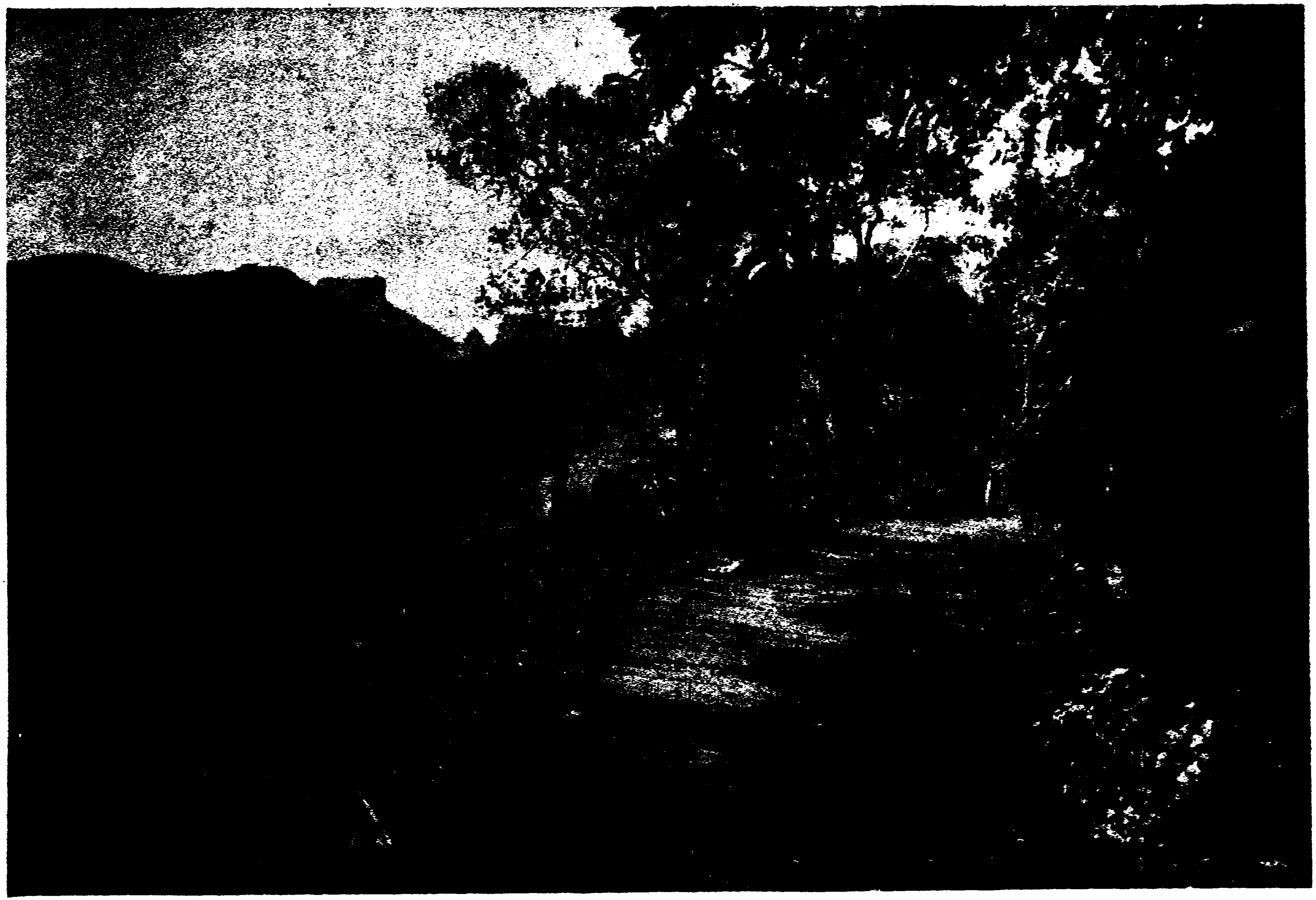
Ever since the establishment of this garden in 1806, it has been under the care and direction of eminent and enthusiastic botanists, who looked upon plants as living things abounding in interest.

[1] Photographs by the author.



THE MAIN ENTRANCE.

THROUGH THE MODEST PORTALS OF THE MAIN ENTRANCE WITH THEIR RATHER PLEASING LODGES ON EITHER SIDE, ONE ENTERS BRAZIL'S WORLD-FAMOUS BOTANIC GARDEN TO MEET ITS SPLENDID COLLECTIONS OF TROPICAL PLANTS FROM THE TREASURES OF THE BRAZILIAN FORESTS TO THE VALUABLE PRODUCTS OF THE LANDS OF THE ORIENT—INDIA, JAPAN, AUSTRALIA, AFRICA AND ISLANDS OF THE SOUTHERN SEAS, ALL HAVE CONTRIBUTED TO THE INTEREST AND FAME OF THE VAST ASSEMBLAGE OF LIVING PLANTS NOW HERE UNDER CULTIVATION.



A SECTION OF THE OVERHANGING WALK

ALONG THE ANCIENT OPEN AQUEDUCT THAT YEARS AGO CAUGHT THE WATERS FROM THE MOUNTAIN SLOPE TO SUPPLY THE YOUNG CITY OF RIO. BEHIND THE OBSERVER STANDING ON THE WALK, IS A SHORT SECTION OF THIS AQUEDUCT CUT IN THE SOLID ROCK. FAR TO THE RIGHT OF THE OBSERVER WE SEE THE RUGGED, FLAT-TOPPED SUMMIT OF GAVEA—THE "CROW'S NEST"—BEFORE HIM LIES THE EXPANSE OF THE ATLANTIC WHILE ALMOST BENEATH HIS POINT OF VIEW AT THE FOOT OF THE STEEP MOUNTAIN SIDE SUPPORTING THE OVERHANGING WALK LIES THE BEAUTIFUL GARDEN OF RIO DE JANEIRO, A VERY LOVELY SPOT WITHIN THE TROPICS THAT NOW IS A SOURCE OF PLEASURE TO ALL WHO VISIT IT.

They delighted in watching the reactions of the plants towards each other in communities, their response to changes of soil conditions in their new surroundings and to the effect of variations in temperature, food supply, and the like, together with possible modifications in their usefulness or economic values under cultivation.

The laying out of the grounds and arrangement of the trees and flowers are pleasing, while the naming of the many avenues, called "*Aléas*" in Rio, and the placing of attractive monuments to commemorate those botanists who helped in the development of the garden add a further interest that includes an expression of a merited appreciation of their work.

In 1932 the garden was incorporated with the Biological Station of Itatiaya and other scientific agencies. The organization now embraces with the Biological Station and Botanical Garden, the Library, Herbarium, agricultural entomology, phytopathology, agricultural genetics and ecology. Dr. Paulo de Campos Porto is director of the entire organization, reporting directly to the Secretary of Agriculture.

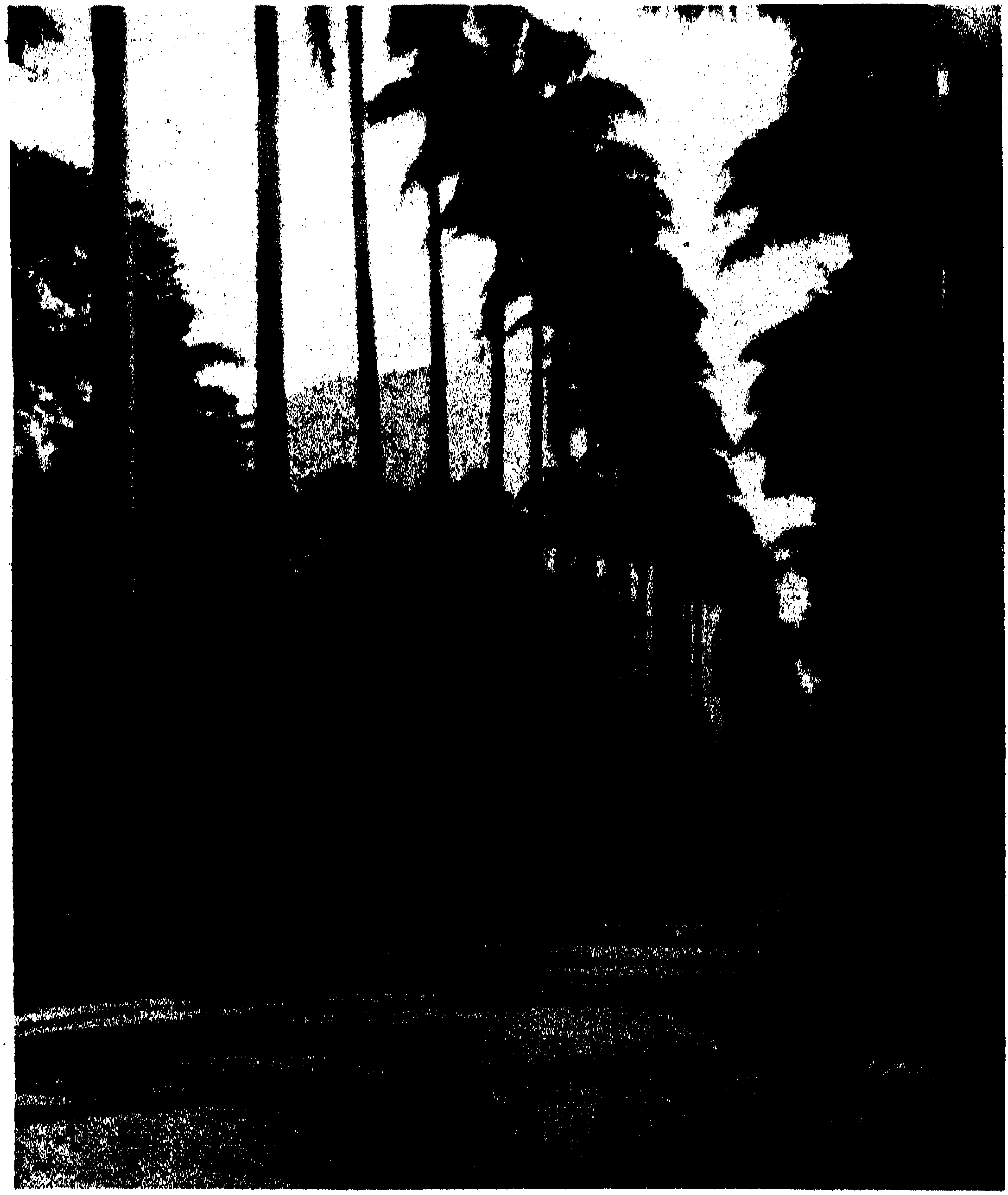
Other activities recently undertaken by the director are courses of instruction in botany bearing especially on the modification of plants due to changes of habitat, and occasional exhibitions of plants grown in the garden, possessing special features of attraction or public interest.

In 1935 the garden contained nearly 140 acres, with about eighty acres of land under cultivation. The collections, to which additions are constantly being made, contain species representing 196 families.

My first visit to this garden was in 1910, during a brief stop at Rio while en route to Buenos Aires, Argentina. Years later I was again in Brazil, remaining at Rio for nearly a year, and during this period visited the garden many times. The days were always too short when espying lovely flowering plants and delicately plumed ferns along secluded paths and fascinating glens, or when, in more restful moods, I leisurely strolled through quiet avenues bordered by massive palms of towering height, or shaded by leafy trees glorified at times by fragrant blooms.

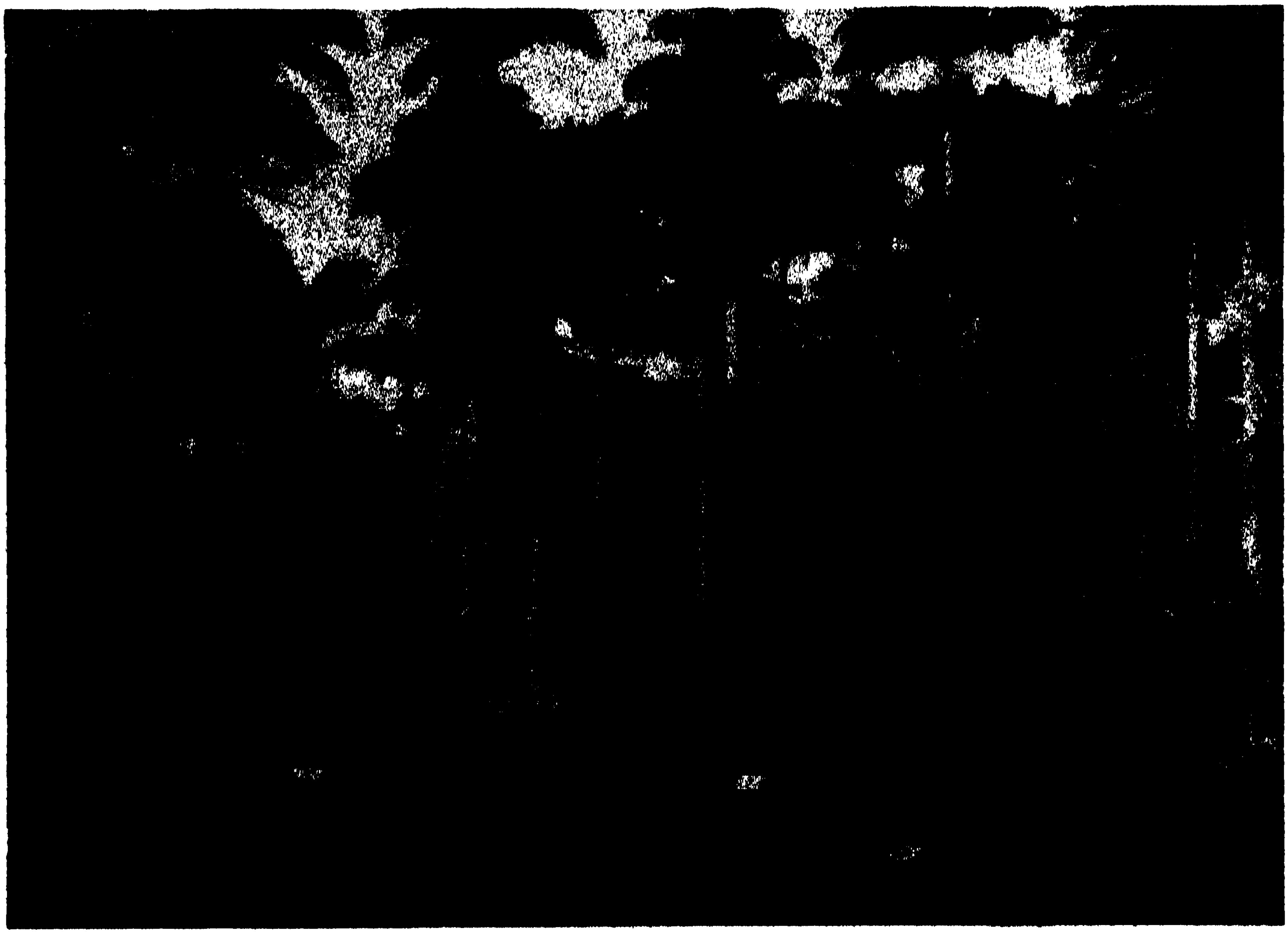
Here and there standing, singly or in groups, were trees that recalled familiar pictures in old-time geographies. There were tea plants and coffee trees from China and Java; the traveler's-tree from Madagascar; the beautiful mango, whose delicious fruit is now common in the markets of our larger cities; the breadfruit tree, and its relative the Jack-fruit or "Jacka" (*Arctocarpus integrifolius*), the strangler tree (*Ficus Benjamina*), named "strangler" because of its habit of sending out many aerial roots or *lianes*, that in their growth touch and coil tightly around the trunks of nearby trees, finally strangling them. There were the more common date and coconut trees, two of the 160 or more kinds of palms in the garden's collection; and several specimens of the great silk cotton tree (*Ceiba pentandra*), remarkable for its great height and the huge sustaining abutments at its base. The section devoted to bamboos—those wonderful giant grasses that in India are classed with the forest trees—occupies a place around Leandro Lake, a charming center of interest to visitors.

There are small streams, cascades, tiny lakes and pools which are the home of pickerel weed (*Pontederia cordata*), several species of pond lilies (Nymphaea), and the royal *Victoria regia;* lotus plants, papyrus, the ancient paper plant from the shores of the Nile, and other aquatics, all of which added beauty and interest to the landscape. There were nearly six thousand kinds of living plants here from many countries, every species of some economic or scientific in-



PALMS ALONG THE GARDEN FRONT.

PASSING THROUGH THE PORTALS WE NOTE A "PARTING OF THE WAYS"—FOUR GREAT AVENUES RADIATING FROM THE ENTRANCE, THE MAIN ONE GOING DIRECTLY ACROSS THE GARDEN. THIS IS THE "CENTRAL AVENUE OF PALMS." IT EXTENDS IN A NORTHWESTWARD COURSE ACROSS THE GARDEN TO ITS LIMITS AT THE BASE OF THE HILLS THAT FORM THE WESTERN BOUNDARY TO THE GARDEN AREA. *Aléa Custodio Serrão* LEADS FROM THE ENTRANCE WESTWARD TO THE "MOTHER PALM," AND MONUMENT TO D. JOÃO VI. BY WHOM THE GARDEN WAS DEDICATED IN 1808. A BEAUTIFULLY TREE-BORDERED AVENUE EXTENDS DUE NORTH TO LEANDRO AVENUE. INSIDE THE GARDEN WALL AND ALONG ITS FRONT IS ANOTHER PALM-BORDERED AVENUE 2,000 FEET LONG THAT IS BISECTED WHERE IT PASSES THE MAIN ENTRANCE. IT IS THIS BEAUTIFUL AVENUE THAT FIRST ATTRACTS THE VISITOR COMING OUT RUA JARDIN BOTANICO FROM THE CITY.



THE FAMILY GROUP.

NEARLY ONE HUNDRED AND SEVENTY SPECIES OF PALMS ARE RECORDED AS BEING CULTIVATED IN THE BOTANICAL GARDEN AT RIO. THOSE WHICH APPEAR IN THE "FAMILY GROUP" ILLUSTRATE TO SOME EXTENT THEIR VARIED GROWTH AS WELL AS THEIR BEAUTY AND THE MAJESTY OF SOME OF THE TALLER SPECIES. THE FOREGROUND MAKES A FITTING BASE FOR THE TOWERING PALMS THAT EXTEND ACROSS THE SCENE.

terest. To stand in the midst of such a vast assemblage from the plant world of the tropics was a memorable event in the life of one coming from the far rocky hills of Maine.

It is a short but very delightful ride to the Botanic Garden from the center of the city by the Park of Paris, through Rio's most beautiful residential section along Avenida Beira Mar and the curved shore of Botofogo Bay, then close under the peak of Corcovado, a granite mountain 2,310 feet high standing on our right, to Botany Street (*Rua Jardim Botanico*) and the main entrance to the garden itself. The approach to this entrance is heralded by an Avenue of Brazil's royal palms running parallel with the street for two thousand feet, a thousand feet on either side of the portals, facing Lagoa Rodrigo de Freitas and the Atlantic Ocean. These palms, although of comparatively recent planting, are already 100 feet high and beautifully symmetrical in form and even growth. Few gardens have a more attractive entrance or present within their gates larger or more interesting collections of plants from tropical regions.

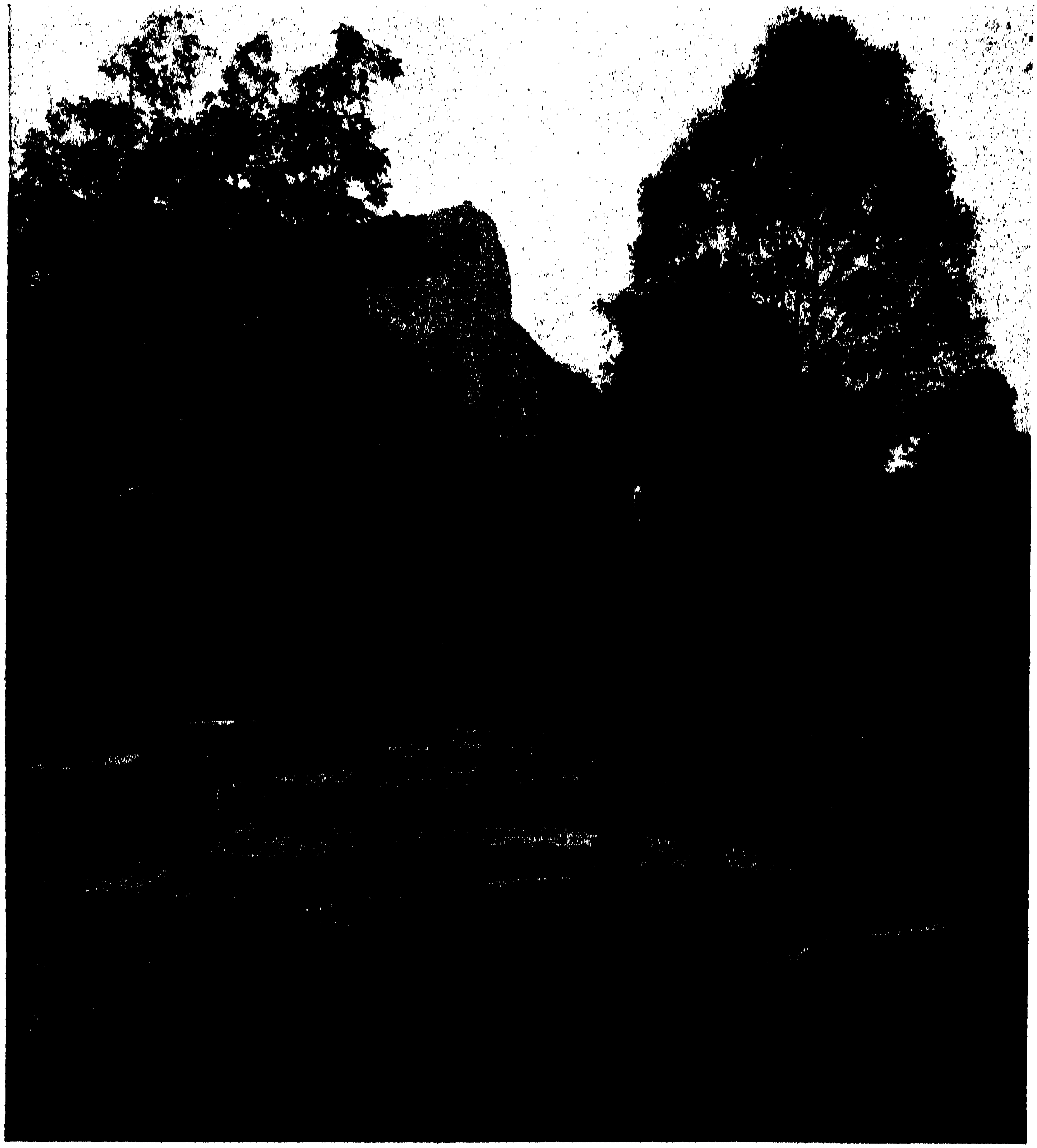
We will now illustrate some of the landscape features of scenic interest and present a number of individual subjects, with captions, showing in a general way, their special attractions.

There are a dozen or more avenues that are bordered by interesting trees. They are quite a feature in the garden and add much to its character and beauty.

The central avenue of those radiating

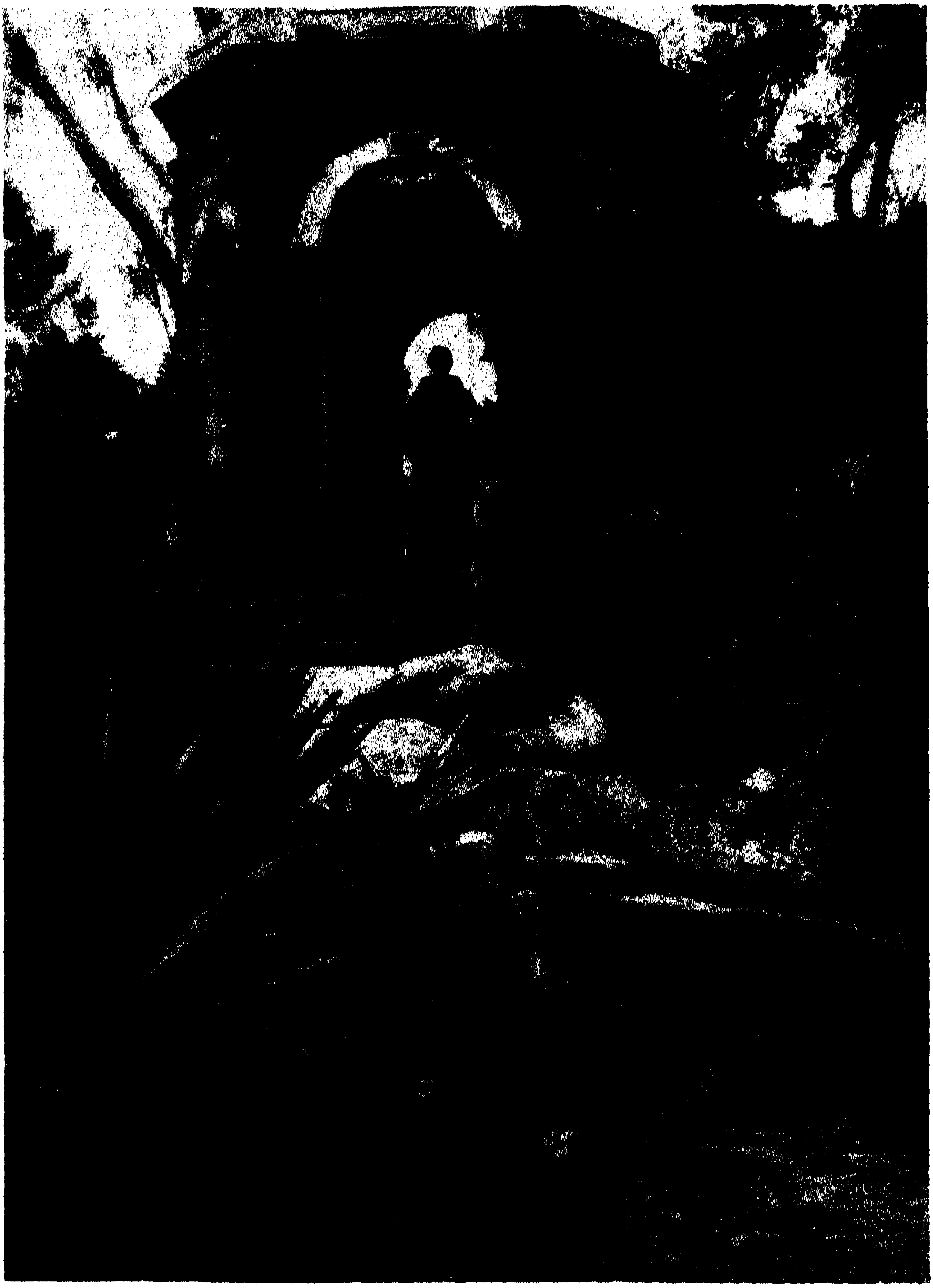
ALLEGORICAL FOUNTAIN.

AT THE INTERSECTION OF LEANDRO AND RODRIGUES AVENUES. THE GREAT CENTRAL PALM AVENUE BORDERED WITH A DOUBLE LINE OF MASSIVE PALMS FROM THE ISLANDS OF THE CARIBBEAN SEA PLANTED HERE ONE HUNDRED AND THIRTY YEARS AGO. NO BOTANICAL GARDEN OFFERS A MORE INSPIRING SCENE, AND NONE HAS BEEN MORE FREQUENTLY PICTURED AND DESCRIBED. THE BEAUTIFUL FOUNTAIN HAS MANY DECORATIVE FIGURES, INCLUDING ALLEGORICAL PRESENTATION OF MUSIC, POETRY, SCIENCE AND ART.



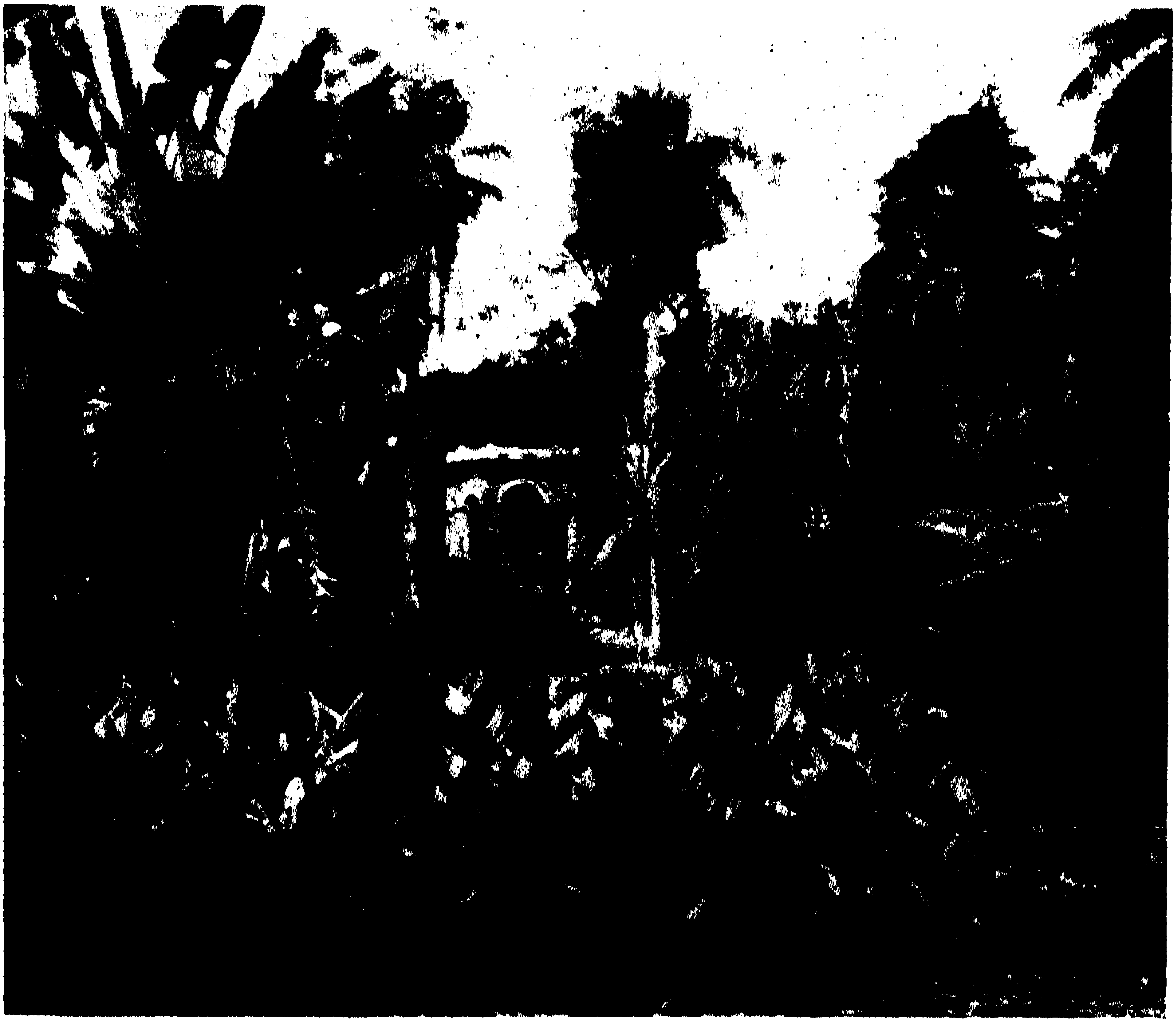
LEANDRO AVENUE.

IN ITS NORTHERN SECTION, BEYOND THE ALLEGORICAL FOUNTAIN, THERE IS IN THE FOREGROUND A SIMPLE FOUNTAIN, OF WELL-KNOWN DESIGN, BEYOND WHICH IT IS BORDERED BY A SPLENDID GROWTH OF *Michelia champaca*, FROM INDIA. THIS TREE IS A CLOSE RELATIVE OF OUR WELL-KNOWN MAGNOLIAS AND IS SOMETIMES CULTIVATED IN THE FAR SOUTH. CORCOVADO FORMS A PLEASING BACKGROUND TO THE SCENE.



MONUMENT DEDICATED TO THE MEMORY OF FREI LEANDRO DO SACRAMENTO, 1762–1809.

FREI LEANDRO WAS AN EMINENT BRAZILIAN NATURALIST AND WRITER ON BRAZILIAN PLANTS. THIS IS AN OCTAGON MONUMENT THAT SHELTERS A FINE BUST OF LEANDRO BENEATH WHICH IS A BRIEF INSCRIPTION DEDICATED TO HIS MEMORY. IT IS ON A SLIGHT ELEVATION CLOSE BY LAKE LEANDRO. THE MOUND IS COVERED WITH INTERESTING PLANTS, INCLUDING A FINE GROWTH OF *Andropogon squarrosus*, WELL KNOWN FOR THE PLEASING FRAGRANCE OF ITS ROOTS THAT YIELD A VALUED PERFUME.



LOOKING ACROSS LEANDRO LAKE.

THE OCTAGONAL MONUMENT HERE OCCUPIES THE CENTER OF THE PICTURE. MASSES OF PONTEDERIA OR PICKEREL WEED, COARSE FERNS, THE ARROW-TOPPED UVA GRASS (GYNERIUM SAGITTATUM), THE TRAVELER'S TREE, WITH ITS BANANA-LIKE LEAVES ARRANGED LIKE A WIDE-SPREADING FAN, AND THE TALL PALMS ACROCOMIA INTUMESCENS, ONE ON EACH SIDE OF THE MONUMENT, GO TO MAKE UP THE PICTURE.

from the main entrance, and extending directly across the garden, is the famous "*Aléa Barbosa Rodrigues*," a "Street of Palms," bordered by a hundred and fifty royal palms of Brazil (*Roystonia oleracea*), whose cylindrical, branchless trunks are like gargantuan columns, gray, smooth and straight, each surmounted by a regal crown of widely spreading emerald green, plumose leaves ever reaching upward to bask in the brilliant light of a tropical sun.

Midway down this central avenue, where it intersects at right angles Leandro Avenue (*Aléa Frei Leandro*), is a large circular pool in which stands an interesting, two-basin, allegoric fountain of ancient design, about 20 feet high. Sitting around the central column above the larger basin are four allegorical figures representing Music, Poetry, Science and Art. When in full operation with its many jets of water spouting outward in all directions from among the numerous figures and cascading over the broad basins, the view is beautiful. The base

THE SUMMIT OF CORCOVADO,

A MOUNTAIN 2,310 FEET HIGH WHICH WE PASS ON OUR RIGHT ON THE WAY TO THE BOTANIC GARDEN FROM THE CENTER OF THE CITY. UPON THIS SUMMIT NOW STANDS A MONUMENT, OVER 100 FEET HIGH, OF CHRIST THE REDEEMER, THAT CAN BE SEEN FROM FAR DISTANT POINTS ON ALL SIDES OF RIO DE JANEIRO AND FROM FAR OUT TO SEA. THIS MOUNTAIN OVERSHADOWS THE GARDEN AND IS THE MOST PROMINENT FEATURE IN ITS SETTING. THE PHOTOGRAPH WAS MADE FROM A POINT ALONG THE OLD AQUEDUCT NEAR PAINEIRAS.

of this fountain is constructed of large boulders partially overgrown by water-loving plants, altogether making a rare and very pleasing picture. The group of young men standing on the far side of the pool emphasize the great height of the palms bordering the central avenue that extends westward to the garden limits in this direction. At this point is located a small Greek temple, seen in the photograph, dedicated to the Goddess of Palms—*Dea Palmaris*—a delightful conclusion to a scene unrivaled for variety and grandeur. No description of Rio de Janeiro is deemed complete without some reference to this remarkable avenue and its majestic trees—it is the Garden's "feature" exhibit.

Leandro Avenue extends northeastward from the octagonal monument that shelters a bust of Frei Leandro, a Carmelite Priest and naturalist, who was the first director of the garden. This monument rests on a mound by the shore of Leandro Lake, which contains many interesting species of water plants. On the mound itself we noted a vigorous specimen of *Fourcroya gigantea* on the left, below which is a species of Azalea; on the right of the stone steps leading up to the monument is a bunch of Vetiver (*Andropogon squarrosus*), an Old World grass valued for its fragrant roots that yield a delightful perfume.

Along this avenue are many interesting trees and shrubs. It crosses the Avenue of Palms at the Allegoric Fountain, and beyond this point is bordered by *Michelia champaca,* a handsome tree related to our magnolias, from tropical India and the Malayan Islands. Its attractive yellow flowers are very fragrant as is its wood, which is useful in construction work of many kinds.

The fountain in the foreground is from Gromort, "Gardins d'Espagne." Corcovado is plainly visible to the north beyond the garden limits, where it terminates a lovely vista.

The Botanical Garden at Rio de Janeiro, with its shaded avenues and well-filled area, is unrivaled in beauty of plan. The landscape architect has made it a delightful place for the public seeking restful enjoyment, while the directorate have acquired equipment that will please the botanist, introducing him to many strange and fascinating members of the plant world. Close inspection of the collections will reveal much to the interested observer, inspiring a greater love for plants and a better understanding and appreciation of their values to human interests.

The garden has attained the ideal of an effective institution of learning, where the plants of the world are brought together in harmonious design for serious contemplation and study. The student may here experience all the delights of original research and discovery, in the science of botany.

IF THE BLIND LEAD THE BLIND SHALL . . . ?

OR REFLECTIONS ON RECENT REVIEWS OF "ANIMAL TREASURE"

By ARTHUR LOVERIDGE
MUSEUM OF COMPARATIVE ZOOLOGY, CAMBRIDGE, MASS.

WHAT is the purpose of a book review? The practice of book reviewing would appear to have arisen in response to the demands of book-lovers subjected to such a spate of literature that they feel the need for guidance as to what is worth-while reading.

If this much is conceded then the reviewer is a person placed in a position of trust; especially would this appear to be the case when his scientific standing or technical knowledge is calculated to lend special importance to his opinions.

These reflections have arisen as a result of reading the reviews of "Animal Treasure" written by Messrs. Clifford H. Pope and Hans C. Adamson in the *New York Herald Tribune Books* (September 12, 1937, p. 3) and the *New York Times Book Review* (October 3, 1937, p. 3), respectively.

"Animal Treasure" is an account by Ivan T. Sanderson of an expedition which he made to the Cameroons to collect zoological material for various individuals and institutions who contributed to the cost. Among these was the British Museum, which subscribed $250, and the Percy Sladen Trust, which was the chief sponsor.

As "The Book of the Month" selection for September, "Animal Treasure" is printed with the artistic skill which one associates with the Viking Press, nor can we wholly blame the publishers for being deceived if such gentlemen as Pope and Adamson give the work high praise. Moreover, Mr. Sanderson gained a tripos at Cambridge, England, which might well be considered evidence of ability to give an accurate account of his observations in West Africa. The present remarks are not in the nature of a review of the book, for that I have done already[1]; they are a challenge to Messrs. Adamson and Pope to justify their reviews.

Mr. Adamson writes: "From cover to cover the book is interesting to the lay-reader aside from such additional value as it may have to the advancement of natural history science" and "the backbone of 'Animal Treasure' is fashioned out of the competent and careful investigations of three men."

Mr. Pope says: "Every naturalist and scientist will devour this book and no lover of nature or adventure should let it escape."

Now to me "Animal Treasure" appeared to be just another attempt at the commercial exploitation of science, and was to so large an extent a compound of misstatement, misinterpretation, exaggeration, sensationalism and emotionalism that one was at a loss to know on what to place reliance.

It is obvious that these diametrically opposing views of the book can not be harmonized, so I should like to ask Messrs. Adamson and Pope whether they really meant to endorse the numerous misstatements made by Sanderson, samples of which are given below and numbered serially for their convenience when replying.

Not the least of Sanderson's mistakes is in referring to himself as a scientist

[1] *Atlantic Monthly*, "Bookshelf," October, 1937; *Copeia*, "*Reviews*," November, 1937.

(p. 14), the bare statement being greatly amplified by some of his admiring reviewers. While it is true that the word "scientist" has been so misused of late that it has become an almost meaningless epithet, in its biological association surely it connotes one addicted to careful, unprejudiced observation, who records his observations without exaggeration, cautious in deduction and with at least some foundation of fact for his theorizing—in other words, a scientist is a searcher after truth. I propose to show that in none of these characteristics does Sanderson conform to the requirements.

1. Adamson, credulous co-author of "The Empire of the Snakes," refers with uncritical approval to Sanderson's description of an incident with a "spitting" cobra. " . . . some of the brown liquid fell on my flannel trousers. I did not notice it at the time but a few days later there were tiny holes where it had been, as if acid had been spilt on the material. Imagine the effect of such a substance if it finds its mark—the eyes" (p. 29).

Now observe that the "scientist" (a) never saw the venom fall upon his trousers, (b) but describes its color, (c) and finding holes in his pants some days later, (d) *assumes* the occurrence, (e) then on the basis of his assumption proceeds to *imagine* its effect on the eyes. (f) He publishes this without ever attempting to check his theories with the known findings of the ascertained action of this venom based on careful experiments by well-known physiologists.

On several occasions I have had the venom of "spitting" cobras alight on my bare arms and neck as well as on my shirt; it invariably crystallized rapidly into spicules of a *pale yellow* or clear amber color. I have spoken to at least six Europeans who have received the venom full in their eyes at short range: in only one case—after the instantaneous but transitory painful reaction had passed—was the sight in the least permanently affected.

2. Pope, author of "Snakes Alive," the best popular account of snakes yet published, avoids all mention of Sanderson's encounters with snakes, including the story of a native who was bitten by a snake that he had brought in. The victim remained unconcerned and calm, not so the excitable Sanderson. Despite the court messenger's assurance that the man would not die—and when natives agree that any creature is harmless one may be sure that it is—without pausing to ascertain by opening the snake's mouth whether it was poisonous or not, we are told: "I then cut a very considerable piece of his thumb off and rubbed raw permanganate of potash crystals into the wound" (p. 323). With a wealth of dramatic detail the tale continues to its climax.

Now this species of snake, longitudinally striped red and black, is so distinctively colored and so common that "even the native women recognize it as harmless," so Dr. G. W. Harley, medical missionary of Liberia, informs me. It is one of the first species which a herpetologist would pick out and name on sight when identifying a collection of West Coast reptiles. As the snake was preserved it may be fairly assumed that Sanderson knew its name when writing; why, then, did he withhold it from the reader? Was it because that as *Bothrophthalmus lineatus*, a perfectly harmless colubrine, this unimaginative fact might mar a good story?

On reading this suggestion, Sanderson wrote me (September 9, 1937) that he omitted the name because "there was some doubt as to whether the 'red-and-black-snake' was actually *Bothriophthalmus lineatus* [*sic*], which required further investigation." But Mr. H. W. Parker, curator of reptiles at the British Museum, to whom Sanderson is indebted for the identification of all his reptiles and amphibians, recalls no such doubts (October 4, 1937)! Under any circumstances its identification as a harmless

species must have been known to the author when writing.

3. Adamson seems thrilled with Sanderson's "set-to with a giant hairy spider which came within a millimeter of sinking its deadly fangs into his face." But let Sanderson tell the story himself; he writes that it was "about the size of my two fists held together" and it took "six-foot leaps . . . at anybody who approached it." "As it did so, I felt the most terrifying coldness come over me. In a flash I let out a scream of pure terror and fell sideways into the ditch. Luckily I moved to the left, for the giant spider just brushed by my right ear so that I felt its loathsome furry coldness as it shot through the air to land beyond in the ditch" (p. 226). One can not but wonder at the acute perception of changes in temperature which is involved in the last sentence.

He continues: "When this terrible creature had been drowned, I steeled myself for an examination of her. As soon as I had satisfied myself that she was dead beyond a shadow of doubt, I spread her out in the enamel dish that we used for dissections. . . . The great legs, fully extended in all directions, covered the bottom of the dish exactly, from front to back and side to side. The dish measured twelve inches by eight inches" (p. 227). These statements intrigued me, for, when curator of the Natural History Museum in Nairobi, I had measured a mygale in the collection whose outstretched limbs were eight inches across. Yet when the legs were contracted around the body, as in death, the creature was kept in a specimen jar whose diameter was only two and three-quarter inches across, *i.e.*, much smaller than a single fist.

I therefore requested Mr. R. J. Whittick, who is in charge of the British Museum collection of arachnids, to furnish me with the dimensions of Sanderson's largest spider. He replied (October 4, 1937) that: "The length and breadth of the area covered by the outstretched legs is approximately $19 \times 16\frac{1}{2}$ cm." So that we find the spider which measured 12×8 inches in Africa is apparently only $7\frac{1}{2} \times 6\frac{1}{2}$ inches in London, and is substantially about the same size as the specimen in the Nairobi Museum.

4. Typical of Sanderson's reactions to the unfamiliar is his absurd description of a mantis. "The mantis is a truly terrifying creature, apparently always willing to engage in a battle, even with man" (p. 45). Compare this with Dr. David Sharpe's description in "The Cambridge Natural History": "The Mantidae, as a rule, have a quiet unobtrusive mien, and were it not for their formidable front legs would look the picture of innocence. This appearance of innocence and quietness must have struck all who have seen these Insects alive" (5, pp. 248–249). This conforms to my own impression of these delightful little creatures, of which I usually kept several on the window screens, where they performed yeoman service in keeping down insect intruders. Sanderson says, however, "I dislike these vampires" (p. 46).

5. In regard to the eating of the male mantis by the female, he continues: "In fact the love-life of the mantis consists of this gruesome performance alone, for without it the male is unable to impregnate the female. Only in its writhing death-agonies can it conclude the act of copulation" (p. 45).

This is simply untrue; though the basic fact that a female mantis will on occasion devour her mate, as do the females of certain species of spiders, has long been known to entomologists, and may be read in "The Cambridge Natural History" (5, p. 249).

6. Of a shrew (*Potamogale velox*) we read: "There is a fantastic animal, a veritable living fossil, that inhabits the mountain streams of West Africa . . . nobody has been able to add to or sub-

tract from the original descriptions by du Chaillu. This has led to the *Potamogale's* becoming almost a zoological myth" (p. 228).

Pope, accepting this, refers to the animal as "exceedingly rare," though the American Museum of Natural History, with which he was connected for so many years, received fifty-one examples from the Lang-Chapin expedition. This material was extensively discussed in the *Museum Bulletin* by the late Dr. J. A. Allen. The Museum of Comparative Zoology has five Cameroon specimens; doubtless other museums are also well supplied. Even if not, with such abundant material in the American Museum how can the creature be said to be almost mythical? This is but one of several creatures whose rarity is exaggerated by Sanderson, whether through ignorance of the literature or with the object of magnifying the achievements of his party, one can not say.

7. It is in his attempts at biological speculations that Sanderson blunders most. As an example, let me cite the following: "We captured six diurnal animals in Africa that belonged to groups all the other members of which are exclusively nocturnal. All six animals—a snake (*Gastropyxis senaragdina*) [*sic*], a squirrel (*Funisciurus poensis*), a monkey (*Cercopithecus pogonias*), a rat (*Oenomys hypoxanthus*), a flying squirrel (*Anomalurus beecrofti*), and, finally, a lemur (*Galago demidovii*)—were bright green above and yellow beneath, whereas their near-related and nocturnal species were all of other colors" (p. 167).

One hardly knows what to say about such utter nonsense. The snake, squirrel and monkey all belong to groups which are strictly *diurnal,* the rat, scaly-tail and galago to groups which are *nocturnal,* and I am not disposed to accept Sanderson's statement that these latter species are diurnal, with the possible exception of the rat.

Through the courtesy of my colleague, Dr. G. M. Allen, I have been able to examine Cameroon material of all these mammals. Not one of them is bright green above; the nearest approach is the grizzled olivaceous squirrel, and this is the only one of the five with any yellow below, except for a slight strawish stain on the chin of the monkey, whose breast is white. Thus we find that the snake is the only creature corresponding to Sanderson's description of "bright green above and yellow beneath," the squirrel, by courtesy, a second. It is well known to mammalogists that the pelage of mammals undergo no radical changes on preservation beyond a slight dulling and fading with the passage of time. In view of the above, his theory about bright green and yellow mammals need not be discussed.

The explanation would appear to be that he uses scientific names without really knowing the creatures to which they refer; this is obvious in several instances, even with such well-known creatures as the water mongoose (*Atilax paludinosus*) which, says Sanderson, "is elegantly cross-striped" (p. 34).

8. Perhaps one of the most amazing claims in this extraordinary book is that relating to a scincoid lizard (*Lygosoma fernandi*), and here we must give Pope credit for the mild statement that it "will strain the credence of many a reptile man." Sanderson and his companions were returning to camp just as day was waning "when out of the stillness of the evening came that dreadful crescendo whistle." (The adjective may be attributed to the state of nervous tension in which Sanderson appears to have passed his days and nights.) Two of the natives said that it had come from "the head of a long narrow valley ascending the mountain to our right." Sanderson and his companion thought that they "were exaggerating considerably in saying that it had originated so far away." However, they set off, and after what was

apparently quite a journey, "the valley narrowed to a ravine, the sound became gradually more piercing and as we still ascended, its volume increased to an extent that I had never believed possible; *in fact, I have never met a louder sound caused by an animal.*[2] The whole air literally reverberated each time that it swelled forth. It might have been a really powerful fog-horn" (p. 201).

The sound ceased; so the party sat down in the fast-gathering dusk, then "From beneath the very next clump of grass to that on which I was sitting that awful whistle began; but as I whisked round, it was cut short before reaching the peak of its crescendo." Surrounding the clump, they found nothing but a steeply descending burrow, in a branch of which they killed a skink. Sanderson continues: "So this was the phantom. No wonder nobody had ever suspected its true origin. Lizards are a silent group except for the geckos, and none other has ever been recorded that makes a noise like a fog-horn. Many have been disturbed, annoyed, almost driven mad by this noise in Africa; they will know what to hunt now" (p. 202).

When Sanderson returned with this story to the British Museum, he was told that skinks were considered a voiceless group and counseled to dissect some specimens to ascertain if there was any physiological basis for the idea before publishing so startling a claim. Instead, the "scientist" approved by Pope and Adamson writes: "Although I have been back now from this expedition for nearly four years, the pressure of work entailed in dissecting rather more important animals has not yet given me time to examine this lizard, and find out how it makes its eerie noise" (p. 203). He then figures the creature under the caption "Whistling Skink (*Lygosoma fernandi*)."

[2] Italics mine to emphasize the powers attributed to a lizard measuring at most eight inches from snout to base of tail.—A.L.

On reading Sanderson's account, and after making due allowance for the writings of an imaginative "zoologist," I was struck by the resemblance of his description to the vibrant shrilling sound made at dusk by sturdy crickets (*Brachytryptes membranaceus*), as they sit in the entrance of their burrows in rather dry grasslands as I have described elsewhere (*Proc. Zool. Soc. London*, 1923, p. 1036). I was unaware, however, whether this species extended its range to the Cameroons, so wrote to the well-known orthopterist, Mr. A. G. Rehn, who recently returned from the Cameroons and was then in Arizona. It so happened that before I received his reply, Dr. G. W. Harley arrived at the museum with zoological material from Liberia. I started to tell him about Sanderson's skink, the sound attributed to it, and the cricket, when he interrupted me to say that he knew both skink and cricket well and that I would find examples of both in his collections. Furthermore, he was familiar with the deafening shrilling of the cricket, and considered my designation of the cricket as the producer correct. He thinks, however, that Sanderson is confusing two sounds, the whistle being the work of secret society men in the forest, so the natives are reticent as to its origin. A few days later I got Rehn's letter saying that he heard *membranaceus* at very many points in his journey across the continent from Kenya to Cameroon and that it was the commoner of the two species occurring in the Cameroons. The fact that the three *fernandi*, which I have personally captured, were silent is no evidence, but I am sufficiently convinced that my explanation, and not Sanderson's, is the correct one despite his claim that the dying lizard emitted a faint replica of the noise while in his hand. If a cricket had given a chirp nearby he might easily have mistaken it.

9. Both Adamson and Pope are duly impressed with Sanderson's "nasty en-

counter with baboons." The account is chiefly amusing as a description of the reactions of an imaginative young man in a strange environment. He was admittedly too terrified to fire until after he had run away. Who has ever heard of drills attacking a man? Were a baboon which had strayed from its true environment into the middle of Fifth Avenue to give an account of the alarming honking and apparent intentions of the automobiles around it, such an account would be about as trustworthy as that of the agitated Sanderson's first meeting with mandrills in the primeval forest.

10. It is not merely under the storm and stress of his emotions that this "scientist" is unreliable; it would appear as if he could not copy from other authors without adding fantastic flourishes from his fertile imagination. Writing of the toad *Nectophryne batesii*, he says that Mr. G. L. Bates "found a male sitting on a brood of eggs laid in a little cup made by neatly sewing together two pendent leaves" (p. 94). It never occurred to him to explain the not unimportant point as to how a toad does sewing.

Compare his description with what Dr. G. A. Boulenger actually wrote: "Mr. Bates has sent me a specimen, a female *N. batesii* with empty oviducts, found by him at Bitye, Aug. 12, 1909, under the trough or hollow of a plantain-leaf petiole, crouched in the midst of a mass of eggs." (*Ann. Mag. Nat. Hist.* (8), 12, p. 71.) In other words a female, not male, was found ensconced upon her eggs beneath the base of a banana leaf apparently lying on the ground.

11. This is the author of whom Pope writes: "He also convinces one that the truth about wild animals is quite as thrilling as the most carefully constructed fabrication"—the same Sanderson who states that he "even saw a reason for the endless repetition of false statements about the majority of animals" (p. 13), who understands "why one expensive expedition after another was returning, having done little more than spend its money" (p. 13).

That truth may prevail, Sanderson explains the primary importance of selecting expedition personnel with due care, for of the applicants about "half will probably be zoologists. These must be eradicated without delay because there is nobody with less imagination or more hide-bound notions of procedure than the average young zoologist" (p. 15). From this one may conclude that the author does not consider himself an average young zoologist: a distinct matter for thankfulness, for if Cambridge were turning out more of the Sanderson type zoology would become a byword.

But let him continue to state his opinions. He writes: "Upon this subject I hold views diametrically opposed to everybody else's, the medical world and people who have lived in the tropics not excluded." "For the tropics and hard work weed out all the athletes, sportsmen . . . select all those who are at least used to and at ease in smoky bars, airless cabarets, and crowded subway trains. . . . Last come questions of compatibility of temperament and similarity of tastes" (p. 15).

So he chose an old Parisian acquaintance named George. "George fulfilled all the conditions." One not unnaturally looks forward to reading of the excellent health enjoyed by so hand-picked a couple; nothing of the kind, however, for we constantly come across such statements as the following: "When George got persistent low fever and was told that he was dying of consumption I rushed him down to the coast meanwhile wiring frantically for someone else to be sent out to me to take his place" (p. 16). "George had . . . returned to the base for a rest because persistent low fever

made him feel, as he put it, like a dish of scrambled eggs. I was shivering myself . . ." (p. 118) or "I was lying under my mosquito net shivering and aching with an attack of malaria" (p. 36). Sanderson should forgive his readers if they are not very impressed with his revolutionary theory of the type of men desirable for the tropics.

12. "Since sundown (and our frugal meal) we had been busily employed measuring, examining, and cataloguing the day's catches. The incessant beating of the rain upon the taut canvas above was only fitfully dispelled by blasts of stentorian jazz produced by the gramophone" (p. 90). Judging from similar frequent allusions to the gramophone it would appear that the "scientists" could only work when it was blaring. Perhaps in this we find an explanation of erroneous measurements and misstatements, for Sanderson assures us that he "kept a very detailed diary in Africa" (p. 17).

"A youth donned the juju mask and executed a dance before me with a young girl. My eyes nearly popped out of my head as it proceeded, for . . . it was the *beguine,* . . . well known to me from happy evenings spent in the supersophisticated cabarets of Paris" (p. 25). "There happens to be a group of persons of most undoubted African descent now resident in America who call themselves—or are called by their manager—the Washboard Rhythm Kings, and they make music. Their records were a particular passion with us, one of them in fact being the expedition's national anthem and always employed as an opening number" (p. 233).

13. Pope actually refers with approval to Sanderson's imaginative descriptions of the forest and its fauna, such as: "One of the first laws revealed to us was the unsuspected fact that the life of the jungle is like that of the ocean floor. This has never been observed or remarked upon before. Everything drifts slowly hither and thither as if wafted forward by currents and cross-currents. To stand still is to arouse suspicion, just as a diver, who can actually handle fish and other sea creatures provided he drifts with them across the bed of the sea, becomes an object to be feared and shunned as soon as he remains immobile and anchored. When hunting, we adopted two entirely different methods. George concealed himself at some vantage point and waited for the waves of forest life to drift by him; I drifted and eddied with the animals themselves. Doing this, I learnt many things and so did he. The speed at which I drifted, I found, must vary with the weather. Bright fine days brought life almost to a standstill. In a hurricane I had to run to keep pace with things" (p. 75).

To the reader it is interesting to trace the continuity of the author's mental processes from the days when "Somehow the ideas of sunlight, beasts, and palm trees got all mixed up in my childish fancies" (p. 12).

14. Sanderson apparently assumes that the memories of his readers are as short as his own. As Discoverer of a New Idea (p. 14), he says: "Scientific methods of collecting animals were out of date" (p. 13). "We went not to shoot, nor merely to collect, but actually to study the animals in life and record their differences of appearance, behaviour, and habits as they really are in nature" (p. 17).

How soon these ideals were forgotten can be seen from cover to cover of the book. "Gong-gong's call to arms was the signal for a wild scramble for loaded shotguns, always kept to hand" (p. 23). "For a whole year (*sic*) we waged ceaseless warfare against the hawks, and on only one occasion did we obtain the same species of bird twice" (p. 24). "Their only use to us was as targets for shooting practice, and fine sport they provided

for this'' (p. 24). Why this ruthless destruction of wild life, for not a single bird was preserved?

Another example of nature study will be found in the account of the killing of a python which, but for their fears, Sanderson and his boy Dele might easily have captured alive. This even if we accept Sanderson's measurement of ''ten feet six and a half inches.'' Note the confidence in scientific accuracy inspired by the last half inch. The author relates how he and his companion chopped at the hapless reptile with ''battle-axe'' and ''trapper's friend.'' Sanderson continues: ''After some time of feverish activity in which I cooperated heartily, he seized what appeared to be a bloody clot of earth and began to pull. . . . When I say six and a half inches, I am not strictly accurate, as the head was a mere meaty slush, hacked to pieces'' (p. 64). Probably most museum men will prefer the old methods after all.

15. One of his reviewers speaks of Sanderson's evident love of animals. This is scarcely borne out by the book, where we actually read of his firing random shots in sheer spite for the fright that a company of mandrills had given him. It is true that he ran away to what he considered a safe distance first (see p. 56) as was to be expected ''Being above all a coward'' (p. 25). Again of a hawk we read: ''I decided to take a chance shot at it though I thought it almost certainly out of range'' (p. 25). Elsewhere we learn of an adder ''drowned in a bottle of alcohol'' (p. 30), and ''all the frogs were eventually caught and drowned in the all-absorbing alcohol'' (p. 37).

Now a humane collector would have chloroformed his victims. You have only to take a little alcohol of the strength commonly employed in the preservation of specimens, and sprinkle it on the eyes or on the mucous membrane of the lips, to gain an idea of the sufferings inflicted on creatures as they struggle in, and gulp down, the biting fluid as it ''burns'' into their vitals.

16. While no intelligent inquirer would look in Parisian cabarets for supporters of foreign missions, one has the right to expect a balanced judgment from even a cabaret-trained zoologist if he claims to be a scientist. Though the African continent comprises eleven million square miles and Sanderson has had less than eleven months experience of a very small area, having rejected the claims of Christ for himself, feels qualified to agree with a chief that Christianity is ''the bane of present-day Africa'' (p. 317). And of another chief we are told that he ''soon observed . . . that I had almost as virulent a dislike of Christians as he had'' (p. 297). Elsewhere he refers to a native who had ''been subjected to the indignity and stifling stupor of a mission school'' (p. 281). Prejudice implies prejudging and it is this quality in Sanderson that vitiates his views on mantis, mission and spider alike.

If Adamson approves Sanderson's book in these matters, it is in sharp conflict with the opinions of several of his colleagues who know Africa. Two of them—Professor Gregory and Dr. Raven—in their delightful book ''In Quest of Gorillas'' (1937), again and again refer with warm approval to the work of the many mission stations which they visited in their trans-African journey which ended in the Cameroons. Indeed, Raven, when he contracted sleeping sickness, had good cause to be grateful for the care and ministrations of a Cameroon missionary.

Space forbids my saying all I should like to on this matter. I think of the leper camps I have seen in Tanganyika, where missionaries labor year in and year out, and then I think of Sanderson . . . I think of Paulo, tent boy on my 1934 trip, honest and conscientious to the last degree, his faith so integral a part of his being that they could not logically be

separated. I do not deny that I have known mission boys who have betrayed the trust placed in them, my tent boy in 1930 certainly exploited his scanty mission training, but then there are zoologists who exploit science, though they have had infinitely greater educational advantages than the native.

17. Sanderson, "who wears his great scientific learning so naturally," as one of his reviewers (Dorothy Canfield) says, tells us that he chose the Cameroons "because it had the worst climate and medical reputation in the world" (p. 14) and for this reason might have been neglected by timid zoologists. Supposedly we are to admire his intrepidity, but for the Europeans who, by developing the country and opening it up, made his visit possible, he has nothing but scorn. Yet they live in "the worst climate" year in, year out.

His book opens and closes with sarcastic references to them and to "unspoiled Africa as it was before Europeans began crawling about it" (p. 11) —a statement which is incidentally quite incorrect. The last page but one embodies his reflections on his fellows in the form of a simile to the "dread weaver birds." He writes: "These busy active birds in their bright-orange ruffs with their drab, dingy women-folk seemed to me to be symbols. The beautiful verdant trees were, like Africa, stripped and peeled of their green glory by the activities of beastly busy creatures relying on their numbers and building their ugly nests all over the place. Every nest like every other, just like the drab houses and grim workshops of the dull Europeans who have colonized Africa—as they call it—in order the better to raise their unwanted progeny" (p. 324).

18. Adamson says, "If 'Animal Treasure,' fruit of an expedition conducted by Sanderson at the age of 25, is any criterion as to what he will accomplish in the future, then natural history science and the world of books owe Edinburgh a vote of thanks for having a climate that is cold and damp."

It is on account of the future that I have written as I have done. Sanderson has caused incalculable injury to natural history by disseminating false information, which is, and will be, quoted far and wide. He is even now in New York, engaged in writing a book on Haiti, a country from which he returned recently "with a broken nose and two dragons," we are told.

19. In fairness to Sanderson, however, I must reiterate that the foregoing remarks are not in the nature of a review of his book. Elsewhere I have given him credit for his gift of writing and paid tribute to his artistic talent. He is not a scientist, however, and to prove this I have quoted a few of his grossest errors; there are dozens of others to which no reference has been made.

That there is need and opportunity for able writers to interpret scientific truths in readable guise for the general public is self-evident. It should not be necessary, however, to play fast and loose with truth, nor garble the facts in the process.

20. We all make mistakes, and I think that if Messrs. Adamson and Pope are frank they will agree that they have no experience of Africa or its creatures. That being the case they should never have attempted to review such a book. They are not alone in accepting it as authentic: from coast to coast in these United States numerous reviewers have heralded "Animal Treasure" as a worthwhile contribution to African zoology. I have attempted to show that the reverse is the case.

WHAT IS A PATENT OR PROPRIETARY MEDICINE?

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THE Constitution of the United States, in Article I, Section VIII, enumerates among the powers of Congress the following: "The Congress shall have power to promote the progress of science and useful arts by securing for limited time to authors and inventors the exclusive rights to their respective writings and discoveries."

Under this section of the Constitution the Congress has passed our patent and trade-mark laws. An inventor of a new and useful thing is given the right to make and sell it for a period of seventeen years. A patent is essentially a contract between the government, representing the public, and the inventor. In return for the disclosure of his invention, the government protects the inventor by giving him a monopoly on the making and selling of his invention for a term of seventeen years. The monopoly granted is not the right to make the article discovered, because the inventor possesses that right anyway. The monopoly consists in the right to exclude others from making, using or selling any embodiment of the patented invention during the life of the patent.

Here we have laid down by the Congress of the United States, acting under the Constitution, a definite policy with respect to inventions of new and useful things.

Contrary to the general assumption that the discoverer of a new and useful thing is entitled to exclusive and perpetual rights therein, the policy of the United States government and of all governments is based upon the assumption that a new discovery belongs to the people, but as a reward for the disclosure of the discovery, the inventor can exclude, by means of letters patent, acquired in a lawful manner, any other persons from enjoying the fruits of his discovery for a limited period.

It is expected that at the end of seventeen years the inventor shall no longer enjoy the monopoly under the patent law, although careful and judicious marketing policies will give the inventor a leading advantage over competitors who may decide to avail themselves of the use of any product on which the patent has expired.

In the field of drugs and medicines, the term "patent" has come to have an added significance. Not often does it refer to a medicine or drug on which a patent has been issued. There are, of course, newly developed chemicals or processes for the manufacture of chemicals on which patents can be secured. However, there is no such thing to-day as a "patented" medicine in the sense that the formula for preparing a mixture of drugs has become the basis for issuance of letters patent. The U. S. Patent Office has not been granting patents on mixtures of drugs in recent years, although such was the case in its earlier history.

In this connection it is interesting to examine the dictionary definition of the word "patent." Its meaning is given as follows: "Lying open; open; public; manifest to all; unconcealed; obvious; conspicuous; open to perusal of all, as letters patent; appropriated by letters patent; secured by law as an exclusive privilege; restrained from general use; patented; an official document—letters patent—conferring or granting a privilege; a patent of nobility; a patent conferring right to engage in a particular

trade usually to the exclusion of others; a letter of indulgence; a pardon."

Any one having to deal with laws enforcing regulations with respect to drugs and medicines would be intrigued by the first definition given. A patent medicine, so-called, is anything but a product of which the composition is revealed or which has a formula "open to perusal of all." Common parlance has given the word "patent" with respect to medicines a meaning which is the exact opposite of its dictionary definition, for patent medicines are generally considered secret formula products rather than open formula products.

The trade-mark laws of the United States have been employed in a very adroit manner to perpetuate the monopoly on patented products. If the individual who registers a trade-mark for a patented product is careful enough to apply his trade-mark in such a manner that it will indicate the brand of the patented product rather than the patented product itself, he can acquire unlimited exclusive rights to the brand name and by clever advertising he can continue to enjoy a virtual monopoly on a given product even after his patent rights have expired. Let me illustrate: The term "aspirin" was made synonymous with acetylsalicylic acid from the beginning of the marketing of that product in the United States. A patent was obtained on acetylsalicylic acid, but the manufacturer popularized the product under the name of "aspirin," and "aspirin" became the accepted name rather than the brand name for acetylsalicylic acid manufactured by the holder of the patent. Accordingly, when the patent expired, the term "aspirin" had acquired a place in the language of commerce and in the language of medicine. Exclusive right to the word "aspirin" could not be vested in the originator of the product after the patent had expired, because he had not taken the trouble to preserve the word "aspirin" as his brand name of acetylsalicylic acid.

The introducer of phenobarbital, on the other hand, was very careful to popularize the name "luminal" as the name of his brand of phenobarbital, and when the patent on this chemical expired the trade-mark "luminal" remained in effect and was renewable and is renewable at twenty-year intervals so that other manufacturers of phenobarbital may not use the trade-mark "luminal."

It can readily be gathered from even this superficial discussion of the subject that it is possible by the use of coined trade names registered with the U. S. Patent Office as trade-marks to go a long way toward perpetuating a monopoly on a given drug or chemical. By means of advertising and propaganda, the brand name of the product is made familiar to consumers over a period of seventeen years, and it is then very difficult for others who endeavor to manufacture the product at the expiration of the patent to convince consumers that their product is not an inferior substitute. However, there is greater opportunity to-day through advertising to break down the monopoly granted by way of trade-marks, and there would be even greater opportunity along this line were it not for the tacit understanding among the better class of manufacturers of drug products not to appropriate one another's patented products upon expiration of the patent.

Practically every pharmacy law in the United States makes a distinction in the regulations of the sale of drugs and medicines and the manufacture and sale of so-called patent and proprietary medicines. The regulations with respect to the sale of drugs and medicines are stringent. The regulations with respect to the production and sale of so-called patent or proprietary medicines are very

loose. Legislatures enacting pharmacy laws for the first time, some seventy or more years ago, were importuned to restrict the sale of drugs and medicines to registered pharmacists or persons working under the supervision of registered pharmacists. The patent medicine industry was sufficiently well organized, even in those days, to have inserted in all these laws a provision completely exempting patent or proprietary medicines from the provisions of such laws. The terms "drug" and "medicine" are generally defined in these laws along lines of the definition in the Food and Drugs Act. However, there is, in general, no definition given for patent or proprietary medicines.

When a definition is given, it is usually so worded as to include anything worth including as far as the patent medicine manufacturer is concerned and to exclude anything which would burden such manufacturer with any restrictions or responsibilities.

A definition for patent or proprietary medicine which has become a classic from the legal standpoint because it was handed down in an early court case involving an alleged violation of a state pharmacy law is that given by the Supreme Court of the State of Minnesota in the Donaldson case. It reads as follows:

> It is a matter of common knowledge that what are called "patent" or "proprietary" medicines are prepared for immediate use by the public, put up in packages or bottles, labeled with the name and accompanied by wrappers containing directions for their use, and the conditions for which they are specifics. In this condition they are distributed over the country in large quantities and sold to consumers in original packages, just as they are purchased by the dealer, without any other or further preparation or compounding.

The American Medical Association through its Council on Pharmacy and Chemistry has adopted the following definition:

> The term "proprietary article" shall mean any chemical, drug or similar preparation used in the treatment of disease, if such article is protected against free competition, as to name, product, composition or process of manufacture by secrecy, patent, copyright, or in any other manner.

The Commission on Proprietary Medicines of the American Pharmaceutical Association proposed the following definition:

> In its widest sense, a proprietary medicine is any drug, chemical or preparation, whether simple or compound, intended or recommended for the cure, treatment or prevention of disease, either of man or of lower animals, the exclusive right to the manufacture of which is assumed or claimed by some particular firm or individual, or which is protected against free competition as to name, character of product, composition or process of manufacture by secrecy, patent, copyright, trade-mark, or in any other manner.

This definition probably states the status quo correctly, but if it were accepted as a legal definition the field of "proprietary medicines" would be greatly enlarged and that of "drugs and medicines" greatly restricted.

It is, of course, manifest to any one who has studied the situation that most of the so-called proprietary and patent medicines are mixtures of well-known drugs devised to meet some condition which they are claimed to cure or relieve. The tendency to develop private formulas has been accentuated in recent years to the point where a pharmacist who is educated to prepare and compound medicines based on official drugs and preparations finds himself in a position of great bewilderment when he attempts to practice his profession in a prescription room labeled with new combinations of drugs offered under fanciful names and with prescriptions from physicians calling for all types of combinations of official and unofficial drugs prescribed under names assigned to them by manufacturers and registered as trade-marks.

In order to avoid duplication of names by the manufacturers themselves, the

American Drug Manufacturers' Association maintains a pharmaceutical trademark bureau with which the members of the association can register new names, and these are made available to other manufacturers so as to avoid costly litigation or wasting of time in searching trademark records when it is necessary to coin a new name. A mere glance at this register under two important headings—Digitalis and Ergot, for example—will indicate the "confusion of tongues" that prevails in the modern prescription department when an inventory is taken of these preparations and the difficulty met by the conscientious pharmacist who tries to keep in touch and up to date with this field.

The names for Digitalis preparations registered with the American Drug Manufacturers' Association follow: Digi-car-dalis, Digicardium, Digidin, Digifol, Digifortis, Digiglusin, Digiloid, Digilutea Upsher Smith, Diginfuse, Digipit, Digipit No. 2, Digipura, Digiquin, Digirex, Digismith, Digitalex, Digitaligen, Digitalone, Digitan, Digitex, Digitol, Digitone, Digitora, Digitos.

The names for Ergot preparations registered with the American Drug Manufacturers' Association follow: Ergaloids, Ergo-Aloe, Ergoapiol, Ergoettes, Ergone, Ergonol, Ergophene, Ergophenol, Ergopit, Ergopit No. 2, Ergo-Quinine, Ergosekalo, Ergo-Stat, Ergot Aseptic, Ergotean; Ergot, Fluid Extract, "Formula of 1874"; Ergo-Thaelin, Ergothesin, Ergotole, Ergotora, Ergot Potent, Ergotrate, Ergozin, Ergo Zinc Comp., Ergyne, Erpiol.

Two recent advertisements of so-called ethical proprietaries tell a significant story in a very few words. Parke, Davis and Company are advertising Kapseals Ventriculin with Iron and Vitamin B. The formula is given as follows: Ventriculin—5 grains, this is the proprietary name for Stomach now official in the U. S. P. The next ingredient is Naferon—2 grains, this is Iron and Ammonium Citrate Neutral and then there is some Vitamin B_1 and Vitamin B_2. This mixture is ready made and put up in capsules, but in order to identify the capsules a yellow capsule is used with a black band around the center which makes this a Kapseal rather than a capsule. Not only by coining a name for the ingredients, which are common official drugs, but also in the manner of dispensing did Parke, Davis and Company appropriate to itself the exclusive right to this formula. A pharmacist putting up Dried Stomach and Iron and Ammonium Citrate Neutral with Vitamins supplied in some form in a plain gelatin capsule would be a substituter and guilty of a heinous offense. A general merchant selling Kapseals Ventriculin with Iron and Vitamin B would be wholly within his rights under the pharmacy laws, because undoubtedly Parke, Davis and Company would claim that this is a proprietary preparation. The reference here has been to a medicine which would be prescribed by physicians ordinarily, but which will soon become an article of commerce if it is found to be of any value in some special condition and the word is passed along from one patient to another. For the present, it will doubtless remain a prescription product, but the common patent medicines of to-day have been prescription products in the past.

E. R. Squibb and Sons have recently announced the marketing of Ammonium Mandelate under the name of Mandamon. The Squibb brand of Ammonium Mandelate is trade-marked under the name of Mandamon. Apparently it is not sufficient to specify "Squibb" in connection with Ammonium Mandelate. The physician is importuned to prescribe this product under the name of Mandamon, and hence the pharmacist who possesses a chemically pure Ammonium Mandelate in

his stock would be considered a substituter if he were to supply this upon a prescription calling for Mandamon.

If there is to be any control over the sale of drugs and medicines, a way must be found to extend that control over all medicines, regardless of the fact that they are classified as "patent or proprietary preparations" through the arbitrary use of these terms in our pharmacy laws or through a conversion of the meaning of these terms to suit the purposes of manufacturers.

A good illustration of the further abuse of privileges granted in connection with the sale of patent or proprietary preparations is the insidious development of taking common official drugs and medicines, changing their formulas slightly, giving them fanciful names and palming them off as new discoveries to be sold without the restrictions that govern the sale of drugs and medicines. A case in point is the Citrate of Magnesia situation with which many states are confronted to-day.

The Crescent Bottling Works of Newark, N. J., has been supplying general merchants with a product labeled "Duke's Magnesia Citro-Tartrate," which upon analysis was found to be a Solution of Citrate of Magnesia approximating the U. S. P. formula but somewhat deficient in Citrate of Magnesia according to the U. S. P. standard. Under the laws of New Jersey, Solution Citrate of Magnesia, being a drug and a medicine, can be sold only under the supervision of a registered pharmacist. By a slight alteration or adulteration of the U. S. P. product and giving it the name "Duke's Magnesia Citro-Tartrate," the attempt was made to classify this product as a patent or proprietary medicine which, under the laws of New Jersey, may be sold to any one without supervision. The facts in the case were brought before the Court of Chancery of the State of New Jersey because the Board of Pharmacy had taken the position that Duke's Magnesia Citro-Tartrate was a medicine and a drug and not a patent or proprietary medicine within the meaning of the pharmacy act, regardless of the name which had been appropriated by the manufacturer. In the district courts, merchants who had sold the product were penalized when the board demonstrated that the product sold was an adulterated Citrate of Magnesia preparation in a Citrate Magnesia bottle but with a fanciful name. The manufacturer, considering himself aggrieved because such procedure led to reduction of sales, went to the Court of Chancery for the purpose of enjoining the Board of Pharmacy from enforcing the pharmacy act in accordance with its interpretation. A temporary injunction was granted, but upon final hearing the vice chancellor hearing the case held that "the product in question was merely common Citrate of Magnesia, a recognized drug preparation, slightly adulterated and of slightly less potent character, and hence within the prohibitions of Section 2 of the pharmacy act." Accordingly, he vacated the preliminary injunction and dismissed the bill.

The manufacturer carried the matter to the Court of Errors and Appeals, which is the highest court in the state, and this court upon reviewing the evidence gave it as its unanimous opinion that "on the evidence, the above finding of fact is manifestly right." Accordingly, the decree was affirmed.

This indicates clearly that when the nature of the subterfuge practiced by manufacturers under the exemption clause of the pharmacy acts is presented to the courts in its true light, they are not fooled. It also indicates that the clause in most pharmacy acts which exempts so-called patent or proprietary preparations from their provisions is not iron-clad, but is in fact vulnerable if enforcement

agencies will take the trouble and pains to establish the facts.

In the writer's judgment entirely too much has been taken for granted in connection with this exemption clause. It does not seem logical that the courts of the United States are willing to give the patent medicine manufacturer the benefit of every doubt all the time. In most instances where court decisions have been rendered on this subject there has not been as much expert testimony and expert legal guidance in the presentation of the case on the part of those opposing the patent and proprietary medicine interests as there has been on the part of these interests.

An illustration which might be cited is in the field of proprietary disinfectants. In some states it is unlawful for any one to sell poisons except under the supervision of a pharmacist. Manufacturers of insecticides and disinfectants containing poisons have adopted the simple expedient of leaving off the label the word "Poison" in cases where their product is shipped into states requiring sales to be made under the supervision of pharmacists. A case in point is the product Klenol. First it was supplied in New Jersey with a poison label. When the company manufacturing this product became aware of the fact that the New Jersey law prohibits the sale of poisons except under the supervision of pharmacists, the product Klenol appeared without a poison label. It is the same product and the question arises, is it or is it not a poison?

Our food and drug laws and our pharmacy laws are very specific in their requirements with regard to the sale of drugs and medicines and with regard to the manufacture of drugs and medicines. As matters stand to-day, the public receives ample protection by law where such protection is least necessary. In the great field of so-called patent or proprietary medicines, almost anything goes and will continue to go until we correct the outworn classification of medicines into the present divisions of plain "drugs and medicines" with revealed formulas and "patent or proprietary medicines" with secret formulas. Such a classification is purely in the interest of manufacturers relying upon trade-marks and secrecy for the protection of their business interests and contrary to the public interest which demands revealed formulas in open competition for such types of self-medication as may be considered safe and harmless.

Some years ago the Committee on the Costs of Medical Care expressed itself on this question in the following words: "The manufacture and distribution of medicines, because of their intimate relation to the health and welfare of a community or nation, partake of the nature of public utilities. In view of the shifting of control from professional to financial hands, manifested by recent developments in the drug industry, the public interest may require 'regulation' of the industry, through the guarantee of a fair return to investors and the limitation of prices to be charged to consumers."

The first and most important effort in this direction should be the elimination of the arbitrary line of demarcation between drugs and medicines and patent or proprietary medicines. The terms "drug" and "medicine" encompass anything that might be conceivably prepared or distributed under the classification of patent or proprietary medicines. If we classify all remedial agents as drugs and medicines under our pharmacy and food and drug laws, the public will receive equal protection in connection with all types of remedial agents. As soon as we create a separate classification, such as patent or proprietary medicines, whether these terms be synonymous or whether they are given individual meanings, we are draw-

ing an arbitrary line for which there is no justification in fact.

Manufacturers of so-called patent or proprietary medicines have created for themselves special privileges under the laws of the several states, which constitutes the rankest kind of class legislation and which no legislator can justifiably approve when he is confronted with the facts.

We need not deny a manufacturer property rights in patents for chemicals or drugs acquired in a legitimate manner. We may even be justified in procuring by law exclusive rights for limited periods to manufacturers for new discoveries and combinations which are not patentable and which contribute to the general welfare and to the progress of medical science and the healing arts. If the government of the United States and other governments throughout the world consider it a fair and equitable policy to *limit* the *exclusive* rights of inventors to their respective discoveries, why should these same governments grant to those who appropriate the discoveries and the fruits of the labor of other such rights *in perpetuity?*

The legitimate drug industry exists as a subdivision of the medical profession. Its obligations to the people are fundamentally the same as the obligations of other professions which provide medical care. Its legitimate economic interests should be protected, but it is not entitled to a permanent monopoly on the scientific achievements of others nor even on its own scientific achievements. To argue otherwise is to argue in favor of suspension of progress in medical science. That an unfair monopoly exists to-day is apparent to any unbiased student of the situation. That this unfair monopoly hangs largely upon an outworn, outmoded and arbitrary classification of drugs in our pharmacy laws has not been fully recognized. The abolition of this outmoded and unfair classification is in the interest of the public health and welfare and should be brought promptly to the attention of every legislature in the United States with the proper supporting facts.

"MIKES"—A BOTANICAL ENIGMA

By REGINALD D. FORBES

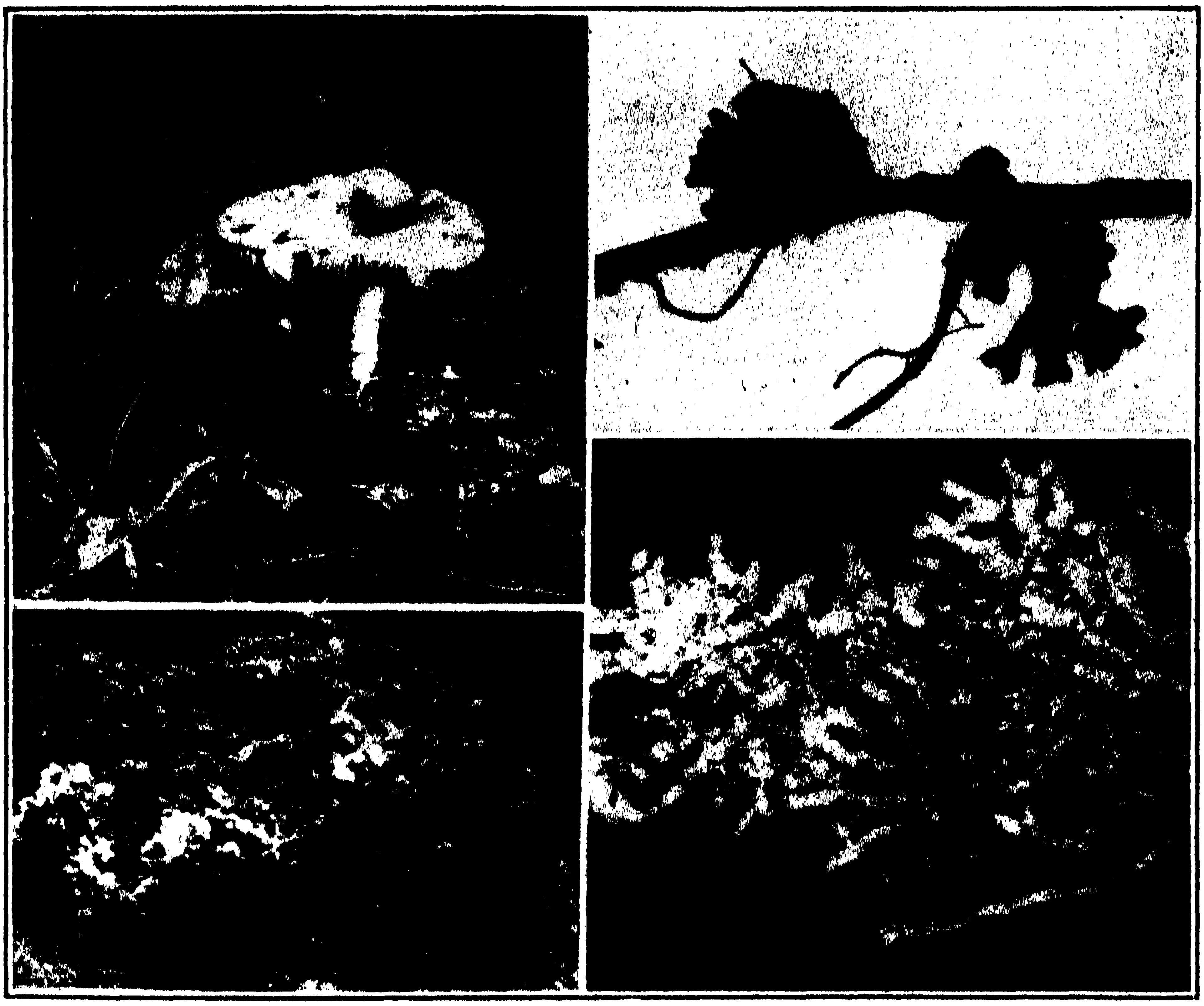
WHEN, seventy-five years ago, the eminent German botanist Frank peered through his microscope at some tiny club-shaped appendages he had found on the fine roots of a spruce tree, he started a controversy which has waged furiously in the scientific world ever since. Because his studies revealed that these appendages were composed of a mantle of extremely tenuous mycelia or vegetative strands of a soil-inhabiting fungus covering the smallest roots of the spruce, he called them mycorrhiza. The "myco" was Greek for fungus, and the "rhiza" was Greek for roots.

Years later the term mycorrhiza on the lips of American students of botany, many of whom possessed "little Latin and less Greek," assumed a distinctly Hibernian flavor, best interpreted in print as Mike O'Rhiza. To the modern student I believe they are known simply as "mikes." Like the impecunious wag who called banknotes above the denomination of $5.00 "Williams," because he was not familiar enough with them to call them "bills," I myself am content to call them mycor-rhiza.

The controversy, however, has not been about pronunciation. The question with respect to mycorrhiza which has split the botanical world is whether this odd combination of a lower with a higher plant is harmful or beneficial to the higher one. Does the mycorrhizal fungus, belonging to a lower order of plants incapable of manufacturing their own food from air and water, with the aid of light, and which ordinarily live on the tissues of plants which have that capacity, in this case also draw its nourishment from the tree? In other words, is this subterranean dweller a parasite, appropriating food intended for the green leaves, far above, of its unwilling host, or does it, as it were, pay for its board by assisting the tree to obtain moisture or plant food from the soil they inhabit in common? This sort of teamwork, known as mutual symbiosis, is not uncommon in nature and has its most familiar illustration in the plant world among the lichens. A lichen is not one plant, but a combination of two—a fungus and an alga. The fungus supplies a tough but translucent dwelling for the alga, which alone of the two has the power to utilize sunlight in the manufacture of enough food from the air to supply both plants.

A third possibility is that the mycorrhizal fungus plays Dr. Jekyll and Mr. Hyde to the higher plant, sometimes contributing a fair share to the combination, like a good mutual symbiont, and at others taking what it needs without giving much in return.

"Mikes" are not rare. In fact they occur almost everywhere. They have been reported from the roots of hundreds of different kinds of woody or perennial plants. In the seventy-five years since Frank first called them to the attention of botanists, Germans, Swedes, Americans, Australians, Britishers, Japanese have described some form of them in their native lands in over eight hundred papers scattered through the botanical journals of the world. In the four states of Pennsylvania, New Jersey, Delaware and Maryland investigators from the Allegheny Forest Experiment Station in 1931 found only one woody plant—the rather rare (for this region) Canada yew—which does not normally bear mycorrhizae on its roots. No wonder that many botanists have seen them and speculated upon their behavior! What

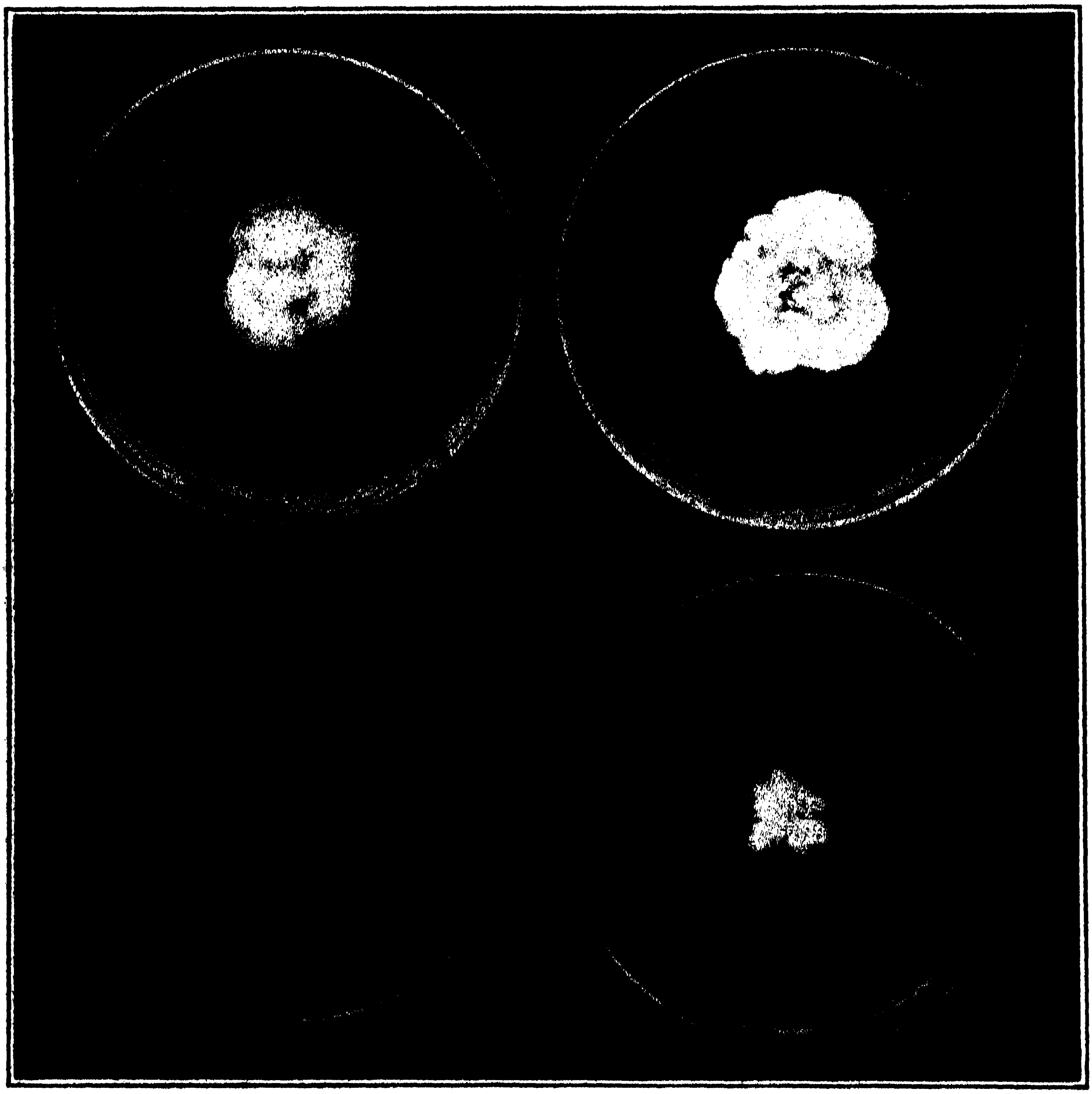


ABOVE GROUND, THE MUSHROOM; BELOW GROUND, THE "MIKE"

(*Upper left.*) THIS MUSHROOM, OR FRUITING BODY, OF THE SOIL FUNGUS *Russula sanguinea*, IS ATTACHED AT THE SOIL SURFACE TO THE THREAD-LIKE MYCELIUM, OR VEGETATIVE PORTION OF THE FUNGUS, WHICH PENETRATES THE SOIL IN ALL DIRECTIONS, SOMETIMES TO A DISTANCE OF SEVERAL YARDS. (*Lower left.*) WHEN THE MYCELIAL THREADS OF THE FUNGUS ENCOUNTER THE ROOT SYSTEM OF A TREE THEY COVER THE SMALLEST ROOTS COMPLETELY, FORMING MYCORRHIZAE ("MIKES"). HERE THE SOIL HAS BEEN OPENED, AND THE MYCORRHIZAL ROOTS EXPOSED. (*Upper right.*) THIS IS A CLOSE-UP OF A LOBLOLLY PINE ROOT AND ITS FORKED MYCORRHIZAE. (*Lower right.*) THIS IS A CLOSE-UP OF MUCH BRANCHED MYCORRHIZAE OF WHITE PINE.

is wonderful is that very few of those scattered over the six continents have sought with determination to read one of the most intriguing riddles in nature. No less a question is involved than whether the majestic oak and the towering redwood are independent organisms, capable of attaining their mighty stature and venerable age through their own efforts alone, or are as impotent as men would be if they had no intestinal bacteria to promote the process of digestion.

No simple investigation is likely to give a thoroughly reliable answer to this question. Trees prosper—or languish—because of so many conditions in nature that it is very dangerous indeed to pick out one particular factor, such as the amount of moisture in the soil, the intensity of light on their crowns, or a hostile insect, plant or animal, and say that it is solely or even chiefly responsible for their condition. And it is particularly hard to study what goes on below ground, where in eternal darkness and in comparative cold the roots of plants avidly seek the life-giving moisture that was yesterday rain or last win-



SOIL FUNGI IN THE VEGETATIVE STAGE

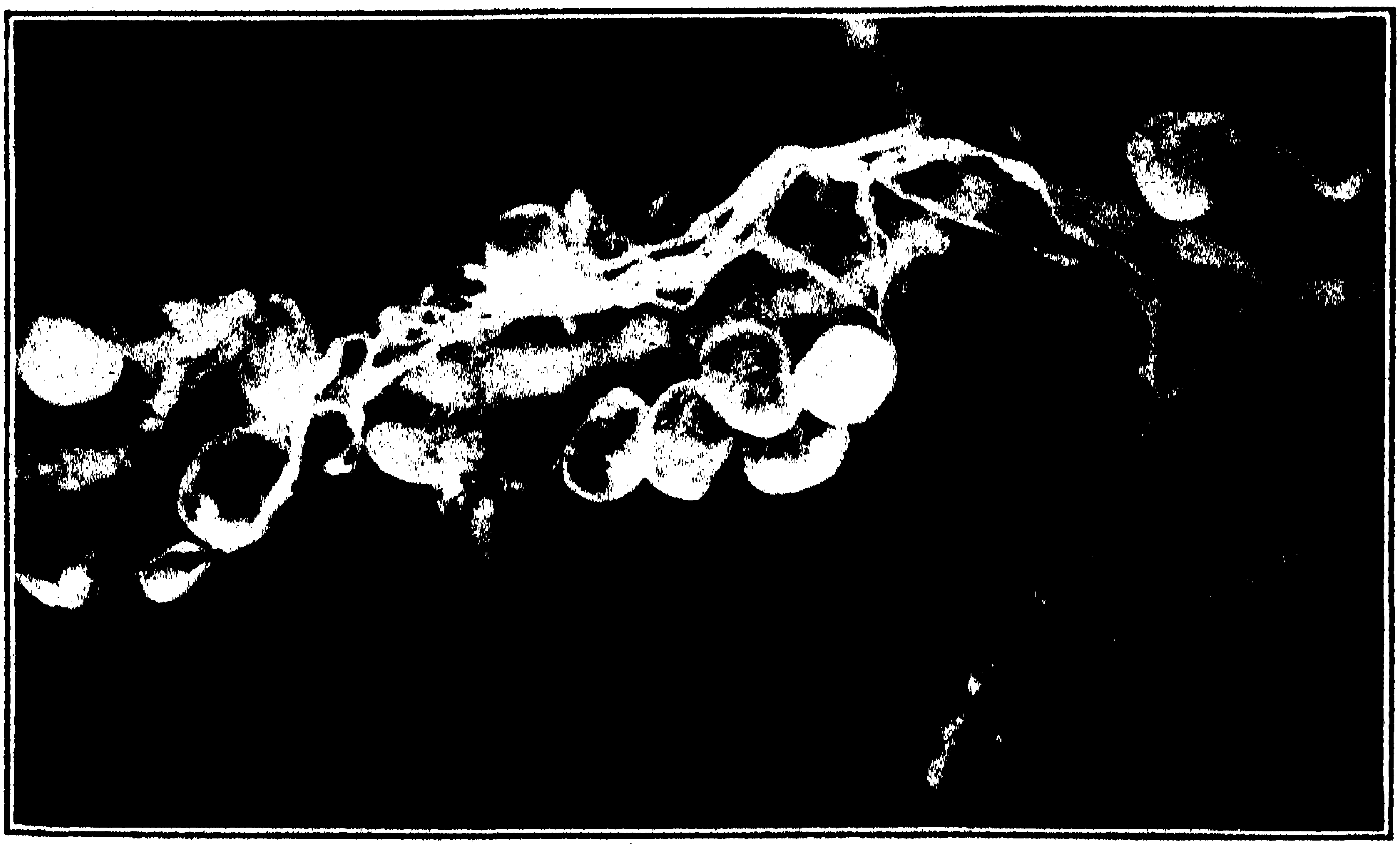
EACH COLONY IS MADE UP OF A DENSE MASS OF MYCELIAL THREADS AND HAS GROWN FOR 14 DAYS ON MALT AGAR IN DISHES. THE TWO ABOVE HAVE BEEN FOUND TO FORM MYCORRHIZAE WHEN PLACED IN CONTACT WITH THE ROOTS OF TREES; THE LOWER TWO HAVE SO FAR NOT DONE SO. MORE THAN 125 SPECIES OF SOIL FUNGI ARE MAINTAINED IN "PURE CULTURES" AT PHILADELPHIA BY THE U. S. BUREAU OF PLANT INDUSTRY.

ter snow. To be quite sure that a particular fungus which grows on the roots of a tree is hurting or benefiting it, we must compare the behavior of this tree with that of another tree growing under precisely similar conditions, but without the fungus on its roots. And because some kind of a soil fungus has formed mycorrhizae on the roots of apparently nearly all trees, some of which prosper and some of which do not, the investigator at the very beginning must learn to identify the different kinds of fungi.

The fungi known as mushrooms are among the most frequent formers of mycorrhizae. The plant pathologist calls them mushrooms, but they include many other kinds than the familiar edible mushroom of our fields, markets, and (alas!) tin cans. Among their close relatives are the puffballs, and in Europe a certain kind forms the truffles which

tickle the palate of epicures, and which tradition says was brought to their attention by the rooting in beech woods of that robust trencherman, the hog. At quite the other end of the scale of edibility, the deadly Amanita, or Death Angel, likewise forms mycorrhizae, as do a large number of other species between these extremes. Some are yellow, some red, but white is the most common color of all. I am referring now to the mushroom itself, the fruiting body or sporophore of the fungus. Mushrooms are borne at certain seasons of the year on the gossamer threads of the mycelium, which have penetrated the soil like roots of a higher plant, but are quite as much the stem and branches as the roots of the fungus. It is the mycelium which, upon encountering the roots of a tree, forms a mantle over the slow-growing side roots that in annual plants develop into root hairs, and also pushes between the outer cells of the tree roots. (Some fungi actually penetrate the root cells; see the photographs.)

Unfortunately, the mycelia of most of the mycorrhizae-forming soil fungi look precisely alike, so that it is generally quite impossible to tell from an examination of the mycorrhizae themselves what fungus is present. Of course, if in a pine grove one finds numerous mushrooms of a certain kind of fungus above ground, and abundant mycorrhizae on the pine roots below ground, one is certainly justified in the suspicion that that particular fungus formed the mycorrhizae on the pine. Once in a great while, perhaps, it would be possible by very delicate excavation to trace a strand of mycelium from the mantle on the pine root to the mushroom on the surface of the ground, thus turning the suspicion into something approaching a certainty. In all other circumstances it would remain a suspicion only. The soil fungus responsible for the mushroom might be quite incapable of mycorrhiza formation, and the fungus investing the pine roots might produce no fruiting bodies at that season or in that year.



FRIEND OR ENEMY?

STRANDS OF THE SOIL FUNGUS, *Lycoperdon gemmatum*, FOLLOWING THE ROOTS OF A PITCH-PINE SEEDLING, ARE AS THREAD TO ROPE IN SIZE. THE MARBLE-LIKE OBJECTS ARE GRAINS OF SAND. NOTE THE SMALL ROOTS AT THE RIGHT.

CULTURE FLASKS CONTAINING VARIOUS SPECIES OF TREE SEEDLINGS BEING TESTED WITH FUNGI FOR MYCORRHIZA FORMATION

THESE FLASKS ARE ARRANGED ON RACKS IN THE GREENHOUSE TO RECEIVE PROPER LIGHT BUT ARE TRANSPORTED TO STERILE CULTURE CHAMBERS IN THE LABORATORY FOR CHANGE OF NUTRIENTS. SOME OF THE SEEDLINGS HAVE GROWN IN THE FLASKS FOR SIX MONTHS. GREENHOUSE OF THE ALLEGHENY FOREST EXPERIMENT STATION, A FEDERAL UNIT HOUSED ON THE CAMPUS OF THE UNIVERSITY OF PENNSYLVANIA.

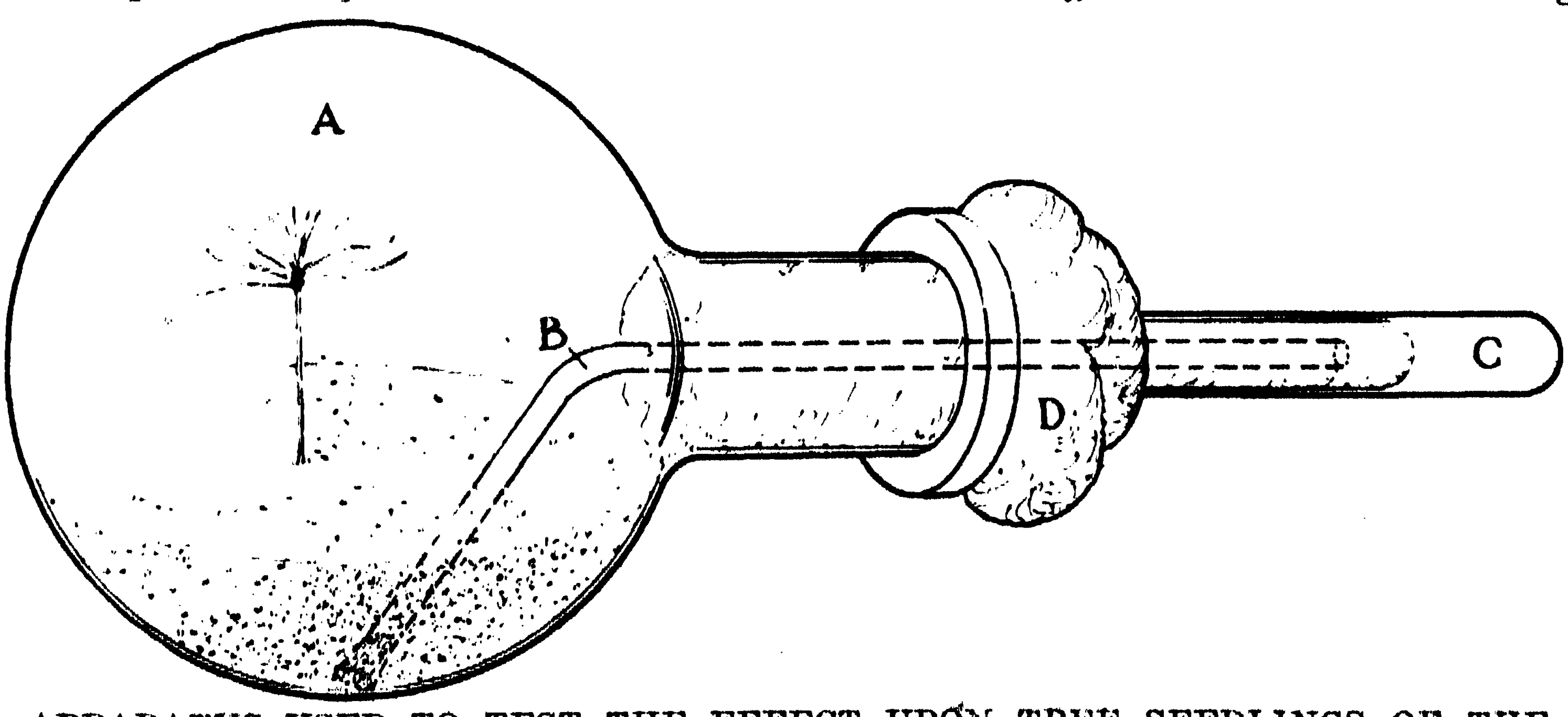
The process of identifying the fungus forming the mantle on a tree root is a long and tedious one. The first step consists of making what is known as a pure culture of the mantle. A tiny piece of the mantle must be removed and, with the least possible exposure to the air, divided between several test-tubes half filled with agar, a substance on which fungi generally thrive. (Glass dishes are sometimes substituted for the test-tubes. See the illustration.) In a few days or weeks there grows on the surface of the agar and on the sides of the test-tube a mass of mycelia, often quite characteristic in color, shape, texture, or other feature. The growth in all the test-tubes inoculated from one mantle must be identical, or contamination by some other fungus or perhaps a mould is suspected. This growth is then painstakingly compared in its appearance and structure with the growth, in similar test-tubes, of fungi previously cultured from mushrooms, which alone of all the parts of a soil fungus may be distinguished with comparative ease and classified. If the test-tube formation cultured from a mycorrhiza is identical with that cultured from a mushroom, the same fungus is responsible for both.

The Bureau of Plant Industry investigators at the Allegheny Station now have a collection of over 125 cultures of soil fungi suspected of forming mycorrhiza, all painstakingly "raised" from different kinds of mushrooms. The chances are good that the culture from a mycorrhizal root obtained in the station territory will prove to be identical

with one of these 125 and can thus be identified. This collection of cultures is therefore a valuable one and justifies the unremitting care that it demands. Some soil fungi are very hardy, growing vigorously in the agar of the test-tubes for weeks without any attention. Others will languish and even die within ten days if not transferred to new agar in a new test-tube. Just why they behave in these ways no one knows, yet many of their food requirements have been determined experimentally.

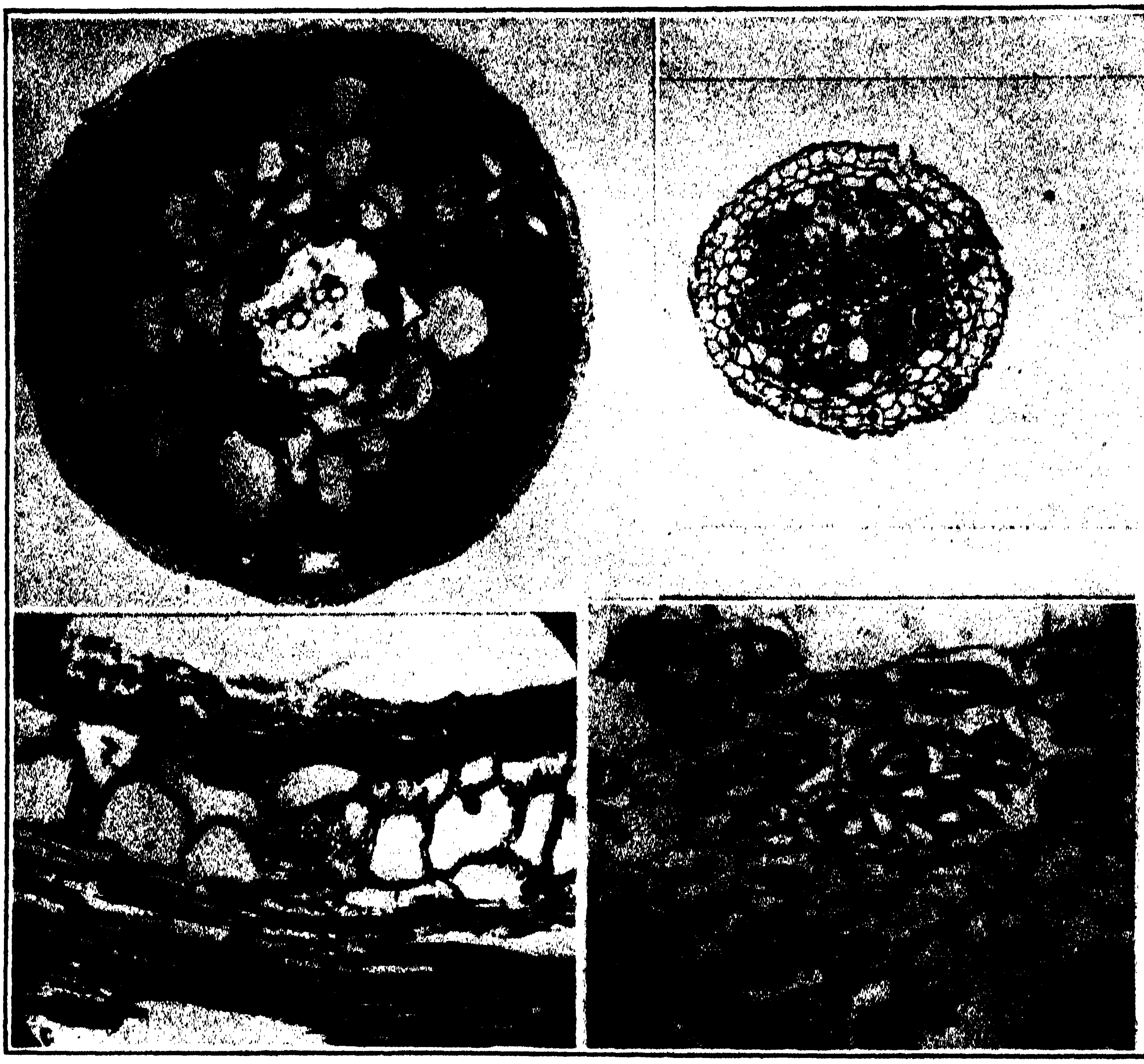
But the real investigator is not satisfied to have identified his mycorrhiza-forming fungus in this way. He will not report the identification as authentic until he has succeeded in re-infecting the particular tree involved with the test-tube fungus. To do this with certainty he must inoculate a seedling of this tree with the fungus under otherwise perfectly sterile conditions—that is, free of every contamination by bacteria, mold, or fungus except the one he is working with, and must keep it growing under these conditions long enough for mycorrhizae to form on its roots.

The process requires of the investigator both ingenuity and great manual dexterity. Because in the woods, and even in the nursery or greenhouse, the tree seedling from the very day of its germination is attacked by a host of living organisms both above and below ground, the student of mycorrhizae must raise his tree from sterilized seed right in the sterile chamber where it is to grow. The chambers—sizable glass flasks with very carefully fitted stoppers—are partially filled with pure white sand, and then thoroughly steam-sterilized to destroy all life within them and the sand. The seed of the tree, sterilized previously and tested for sterility on agar in test-tubes, and a bit of mycelium from the culture of the fungus, are then swiftly transferred in a sterilized atmosphere to the sand in the chamber, and the stopper is tightly fitted. Glass tubes, permanently inserted in the stopper, reach to the bottom of the sand in the chamber, as shown in the illustration, and through these distilled water, in which essential plant foods are dissolved, is introduced into the sand; any surplus is removed by suction. The whole apparatus is then set in a sunlit greenhouse. The seedlings



APPARATUS USED TO TEST THE EFFECT UPON TREE SEEDLINGS OF THE PRESENCE OR ABSENCE OF "MIKES"

THE SEEDLING IS RAISED IN A STERILE CHAMBER PARTLY FILLED WITH SAND, MOISTENED PERIODICALLY WITH A NUTRIENT SOLUTION INTRODUCED BY MEANS OF A GLASS TUBE PASSING THROUGH THE COTTON PLUG CLOSING THE NECK OF THE FLASK. THE WHOLE APPARATUS IS HANDLED WITH EXQUISITE CARE TO PREVENT CONTAMINATION BY SPORES OF ANY ORGANISM EXCEPT SUCH FUNGI AS MAY BE DELIBERATELY INTRODUCED ALONG WITH THE TREE SEED.



"MIKES" UNDER THE MICROSCOPE

(*Upper left.*) CROSS-SECTION OF A FINE ROOT OF LOBLOLLY PINE, COMPLETELY SURROUNDED BY A LIGHT-COLORED MANTLE OF MYCELIAL THREADS, WHICH ALSO PENETRATE *between* THE CELLS OF THE ROOT. SUCH A MYCORRHIZA IS CALLED "ECTOTROPHIC." (*Lower left.*) LONGITUDINAL SECTION OF A SIMILAR ROOT. AT THE TOP IS THE MANTLE, AT THE BOTTOM THE CENTRAL CELLS OF THE TREE ROOT. THE GRANULAR APPEARANCE OF THE LARGE CELL IN THE MIDDLE IS DUE TO A CHANCE PASSAGE OF THE SECTIONING BLADE THROUGH A LAYER OF MYCELIUM SEPARATING TWO CELLS. (*Upper right.*) CROSS-SECTION OF AN "ENDOTROPHIC" MYCORRHIZA OF TULIP POPLAR. HERE THERE IS NO MANTLE SURROUNDING THE TREE ROOT, BUT THE MYCELIUM OF THE FUNGUS HAS ENTERED ITS LIVING CELLS, IN WHICH THE STRANDS APPEAR IN CROSS-SECTION AS TINY CIRCLES. (*Lower right.*) A LONGITUDINAL VIEW OF THE PRECEDING, FURTHER ENLARGED. THE WORM-LIKE OBJECTS ARE PORTIONS OF THE HYPHAE, WHICH HAVE PENETRATED THE CELL WALLS OF THE TULIP POPLAR ROOT AND ARE COILED WITHIN MANY OF THE CELLS.

grow for many months, completely protected from contact with every other living thing than the soil fungus with which the sand was inoculated. From time to time one of the flasks is removed from the experiment and the roots of the seedling are microscopically examined with exquisite care for the presence of mycorrhizae. Sometimes the fully developed mycorrhizae can be seen in the sand against the wall of the flask. Discovery of them completes the identification of this particular fungus as a mycorrhiza-former on this particular species of tree.

The same process and the same apparatus are counted upon some day to yield the final answer to the riddle of mycorrhizae—whether they are helpful or harmful to the tree on the roots of which they occur. Some of each batch of seedlings are not inoculated with any fungus, and their behavior is compared with that of inoculated seedlings. A variety of nutrient solutions are fed to all the little trees alike; they include both organic and inorganic salts containing nitrogen, phosphorus and potassium, which of all the elements required by plants are most likely to be deficient in soils, and the lack of which produces the most prompt and marked effects on plants. The action of the teeming microscopic flora—bacteria and fungi—upon nitrogenous matter in the soil is most complex, and their endless reactions are of even greater complexity. Inorganic nitrogen, such as so-called commercial fertilizers contain, is easy for trees and other higher plants to assimilate, but most forms of organic nitrogen are very hard. Fungi, on the other hand, are quite able to obtain the nitrogen they need from organic sources, such as decaying plant material, and in so doing they may convert it into forms usable by higher plants.

It is this latter possibility that investigators of mycorrhiza-forming fungi believe to be the key to any beneficial effect these fungi may have on trees. To test this possibility they furnish some of their seedlings in the flasks with inorganic nitrogen only, and others with organic only. The signs of nitrogen starvation in seedlings are spindly stems, short and twisted needles, pale green at first and eventually yellow, and reduction in extent of the root system. If after several months certain batches of seedlings should show unquestioned signs of nitrogen starvation in comparison to others, the differences in behavior can be ascribed to the presence or absence of mycorrhizae. The expectations are that the seedlings furnished with inorganic nitrogen will develop satisfactorily either with or without mycorrhizae, unless of course the fungi are definitely harmful; and that those furnished with organic nitrogen will do better if inoculated with mycorrhiza-forming fungi.

Unfortunately the symptoms of nitrogen starvation do not appear at once (distilled water alone, plus air, will allow a newly germinated pine seedling to grow for several weeks) and are obscured somewhat by the unnatural conditions which the seedlings encounter in the flasks—an atmosphere saturated with moisture, light changed in many of its qualities by passing through the glass of the greenhouse and that of the flask, temperatures probably higher than in nature, and complete absence of the great complex of other living things—some of which in the woods undoubtedly react favorably, both above and below ground, to tree seedlings. Furthermore, it is by no means certain that nitrogen assimilation alone is involved; Frank and many students felt that the intake of the essential inorganic nutrient salts, and even of water itself, were influenced by mycorrhizae. The sum total of all these influences, some of which may be unfavorable while others are favorable, might well affect the growth of the seedlings less strikingly than if only one were at work. At any rate, few investigators dare hope for such spectacular results as the speedy death of seedlings having no mycorrhizae, and the vigorous growth of those which have, or *vice versa*. Nature's processes are so subtle, and life is so inscrutable a thing, even to-day, that it is only the layman who expects them to become plain as a pikestaff.

Where trees grow not in the greenhouse but in the forest, it seems reasonable to assume that the environment, particularly the physical and chemical characteristics of the soil, its moisture and aeration, and the relation of the mycorrhizal fungus to non-mycorrhizal fungi and to bacteria, will determine the

balance of power between tree and fungus.

But of what practical value, one may reasonably ask, will be the knowledge that mycorrhizae help or harm the higher plant? After all, it may be argued, can man exert any appreciable control over the flora of the soil? On a large scale, perhaps not. But under certain conditions at least it should be possible to destroy mycorrhiza-forming fungi if they be harmful or to foster them if they be beneficial. Devices for steam-sterilization of the seed-beds in tree nurseries have been developed which will destroy the soil flora to a depth of several inches, and the soil fungi may not invade the sterilized beds for several years. Inoculation of beds with fungi found to be beneficial formers of mycorrhizae also seems quite feasible.

Some very striking results with soil inoculation have in fact been obtained by students of mycorrhizae in England recently and in Australia some years ago. The Royal Forestry Commission attempted in 1924–27 to reforest dreary Wareham Heath in Dorsetshire, England, by sowing several kinds of pine, generally with very disappointing results. The seed germinated well, but nearly everywhere the seedlings died after two or three years of feeble growth. Experimental areas in later sowings, inoculated with small quantities of soil brought from vigorous stands of the same pines as those planted and known to contain mycorrhiza-forming fungi, were reported to produce seedlings notably more vigorous than untreated areas adjacent. In Australia the introduction of forest soil into a tree nursery on land never before forested produced an immediate change for the better in the growth of seedlings; the result was attributed to mycorrhizae. American investigators, however, have not been quite so willing as their English cousins to attribute the better growth of the young trees in these experiments to mycorrhizae. They point out that the soil inoculum almost certainly contained many more species of organisms than the fungi which admittedly formed abundant mycorrhizae on the vigorous seedlings, and were mostly absent from the stunted ones. The Allegheny Station investigators share the presumption that the abundance accounted for the vigor, but point out that there is nothing to prove that both were not the result of some favorable soil condition—increased numbers of bacteria of certain kinds, for example—that was introduced along with the mycorrhizal fungi. The increase in mycorrhiza production may not be the cause of better growth; rather it may follow as a natural consequence of the increased growth, especially of the roots, regulated by other organisms or by chemical changes in the soil.

Should mycorrhizae prove harmful, there is some possibility of control by better methods than the steam-sterilization just mentioned. The steam, unfortunately, kills all species of soil organisms indiscriminately. Certain chemicals might be found to kill selectively—to eliminate the mycorrhizal fungi and spare non-mycorrhizal fungi and bacteria. The fact that some non-mycorrhizal soil fungi have been shown to attack and destroy the mantles of mycorrhiza-formers suggests their use for this very purpose. The latest development in control of the potato scab is inoculation of scab-infested fields with a fungus hostile to the scab. Perhaps the balance of activity of soil organisms, including mycorrhizal fungi, can be regulated in like manner.

PIONEERS IN THE STUDY OF VIRUS DISEASES OF PLANTS

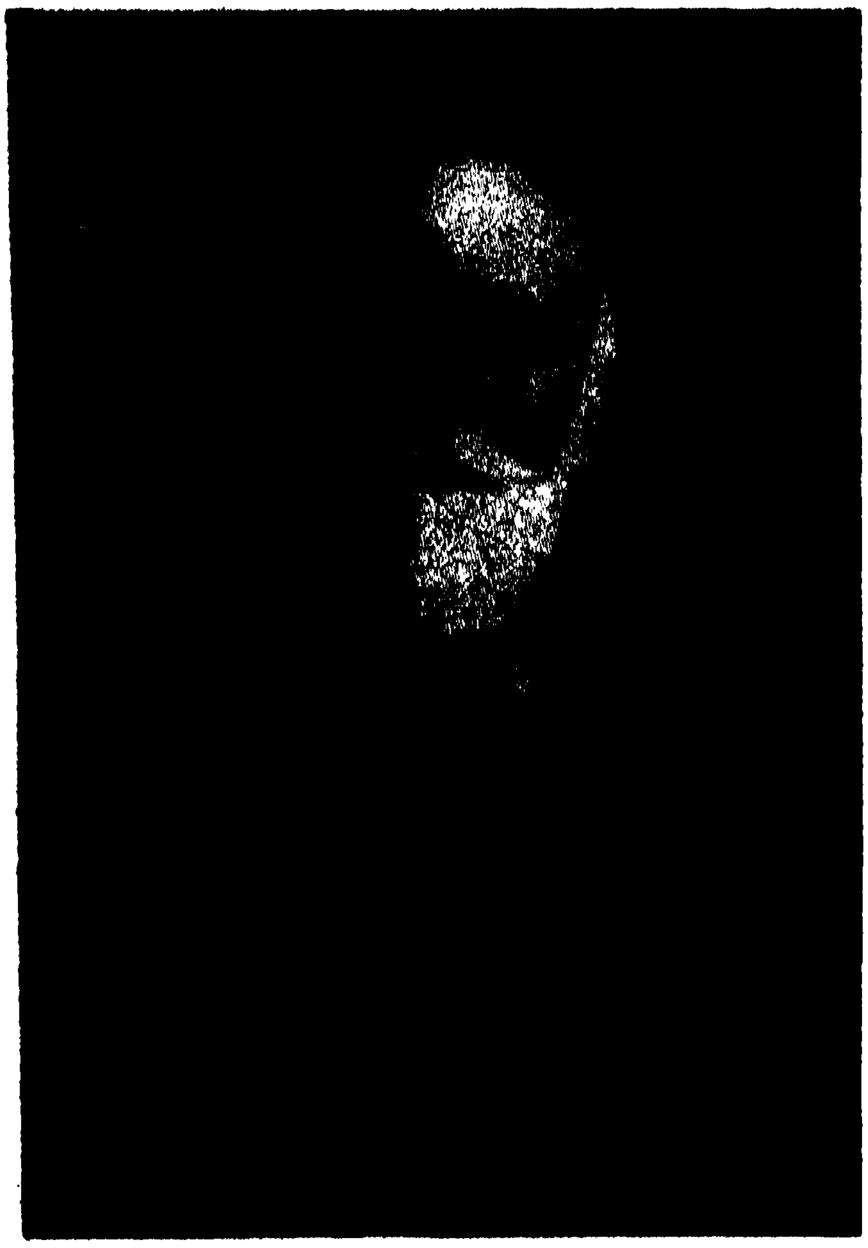
By Dr. MELVILLE T. COOK

PLANT PATHOLOGIST, AGRICULTURAL EXPERIMENT STATION, RIO PIEDRAS, PUERTO RICO

MOST people are interested in the work of pioneers in new countries and in the study of new subjects. Our interests may lie in their adventures or in the new ideas which they suggest. Some pioneers in new fields of study have been in as great danger of criticism and ostracism as their brother pioneers in new countries have been of losing their lives. The heroism of these people always appeals to us, but sometimes the delay between the achievements of these pioneers and the recognition of their achievements has been so great that much of the true personal viewpoint is lost. Very frequently the recognition due these workers does not come until they have passed away, and sometimes it is difficult to determine just who are the true pioneers and credit is sometimes given to the showmen or the brilliant writers rather than to the true workmen. This statement may apply to many classes of people, but the writer has in mind the great scientists of the world who have been leaders. Very few have suffered the fierce criticisms that were fired at Darwin, but many of them have not been recognized until many years after they have passed from the scenes of their labors. The purpose of this paper is to call attention to a group of workers, many of whom are living and active in their researches. They are true pioneers in a new branch of plant pathology.

There are three well-defined branches of plant pathology: (1) diseases caused by fungi, (2) diseases caused by bacteria and (3) diseases caused by viruses. To these may be added a fourth branch to include the various non-parasitic and deficiency diseases which are frequently referred to as physiological. The diseases caused by viruses were at one time placed in this last group by many students. This group is not well defined or well developed. The first and second branches are deep rooted in the past, but the great advancement has been within the last three quarters of a century. The third is a new branch; in fact, it is so new that we are not sure that we know the nature of the causal agents which we call viruses. This new branch has its pioneers, and it is well that we should give them some consideration at this time. These men have not suffered the criticisms that fell to those who pioneered the fields of evolution a few years earlier, but they are true pioneers who have opened the trails for a new branch of science.

The writer fully appreciates that different workers may have different ideas as to the date for the ending of the pioneer period and as to who should be included in the list of pioneers. The writer has arbitrarily placed 1920 as the end of the pioneer period and has selected four Europeans, four Americans who appear to him to be the outstanding research pioneers in this new branch of plant pathology, which we have designated as "virus diseases." The selection of 1920 as the date for the ending of the period appears to the writer to be justified by the literature. In the opinion of the writer the four outstanding Europeans are Mayer, Iwanowski, Beijerinck and Quanjer. The four outstanding Americans are E. F. Smith, Woods, Allard and James Johnson, although several others contributed much to our knowledge of the subject during this period. These men have been selected because they started lines of research which attracted



ADOLPH EDWARD MAYER

and stimulated studies in this branch of plant pathology. It does not include the names of early workers who reported new diseases.

A few virus diseases had been reported long before any of these men began their studies, but in most cases they were not recognized as diseases. They had attracted the attention of horticulturists and a few others who were interested in plants. Some of them were recognized as injurious to economic plants, but in some cases the symptoms were considered of value in floriculture. The breaking in tulips and the mottlings in *Abutilon Thompsonii* are striking illustrations in which the symptoms were considered of value. The mosaic of tobacco in Europe and the peach yellows in the United States were the two injurious diseases that finally forced scientific research.

Adolph Edward Mayer was the first of these pioneers, and the researches into these problems started with his studies. A peculiar mottling of tobacco had been known for a long time and finally became of such great economic importance that Mayer was called to make a study of the problem. The first work was done at an agricultural experiment station in Holland (Rysproef Station Zu Wageningen). Mayer's task was gigantic for the times, and his results show him to have been a true research scientist. He published the first truly research papers on a virus disease. Influenced by the studies in bacteriology which had come into prominence, he believed that these minute organisms were the cause of this mysterious disease. This theory proved to be wrong, but he appears to have been the first to make inoculation, temperature, transmission and dilution studies. He also did some work on transmission by budding. He suggested the name "mosaickkrankheiten," which has been translated into and used in other languages. He pointed the way for research workers.

Dmitri J. V. V. Iwanowski was the second European to attract attention. He was also a believer in bacteria as the

DMITRI J. V. V. IWANOWSKI

cause of tobacco mosaic, but he is known as the first worker to demonstrate that the active agent would pass through a filter that would remove bacteria. This epoch-making discovery was made in advance of the corresponding work by the students of the virus diseases of animals. Also, he was the first to observe the presence of the intracellular bodies in diseased plants, and he believed them to be the results of the disease. A few years later these bodies attracted much attention and some workers believed them to be protozoan in nature and the causes of these diseases, but many workers are inclined to agree with Iwanowski. He studied the structure of diseased plants, reported crystalline bodies and crystals.

Martinus Willem Beijerinck confirmed much of the work of Mayer and Iwanowski and was the first to reject the bacterial theory which brought him into controversy with Iwanowski. He will be remembered as the author of the "contagium vivum fluidum" theory. Although this theory was abandoned long ago, it started research work that has been very fruitful. His influence on research was as great or greater than that of either of the other two. His confirmation of the filtration studies of Iwanowski was made in the same year (1898) that Loefler and Frosch demonstrated that the active agent of foot and mouth disease of live stock would pass through a filter and helped to bring that line of research into prominence. He also studied the structure of the diseased plant and was the first to suggest that the active agent traveled through the phloem. He appears to have been the first to study the effects of chemicals on the active agent.

MARTINUS WILLEM BEIJERINCK

HENDRIK MARIUS QUANJER

A study of the literature reflects the enormous influence of these three men on the study of these diseases for many years. In fact, many of their studies are repeated by students of to-day in the studies of other virus diseases, and some of their discoveries are very generally accepted to-day.

Hendrik Marius Quanjer was the next European to initiate important researches

ERWIN F. SMITH

in Europe. He contributed much to our knowledge of the virus diseases of plants, especially potatoes. In 1908 he started his extensive studies on the necrosis of the phloem tissues of potatoes which have explained some of the phenomena of the virus diseases on this and other important crops. His studies have suggested lines of research to many students of these diseases.

Erwin F. Smith holds a position in America comparable to that of Mayer in Europe. He made the early research studies and compiled records on peach yellows from the time of its discovery down to the time of the publication of his report in 1888. He made studies and demonstrated facts concerning its transmission by budding that are accepted at this time. He was primarily a bacteriologist in the field of plant pathology and was influenced by his studies in that subject and probably by the work of Beijerinck as shown by this paragraph.

"The spread of yellows from diseased buds to healthy stocks, which I have carefully verified, points strongly to some *contagium vivum* as the cause of the disease. If a micro-organism be really the cause, it probably occurs quite constantly in some part of each diseased tree, and this must be established beyond question; it must be clearly distinguished from similar organisms not related to the disease; and, finally, it must be isolated by cultivation in suitable nutritive media and be able to produce the disease when inserted into healthy trees. If from a pure culture of some micro-organism peach yellows can be induced in healthy trees, then the case is closed and there can be but one verdict."

He was the discoverer of the "little peach" disease and made studies similar to those on "yellows." He confirmed the work of horticulturalists who claimed that this disease could be transmitted by budding and demonstrated it was not transmitted through the soil and very rarely by the seeds.

He made a translation of some of the work of Mayer which shows the thoroughness of his attack on this problem at a time when few virus diseases were

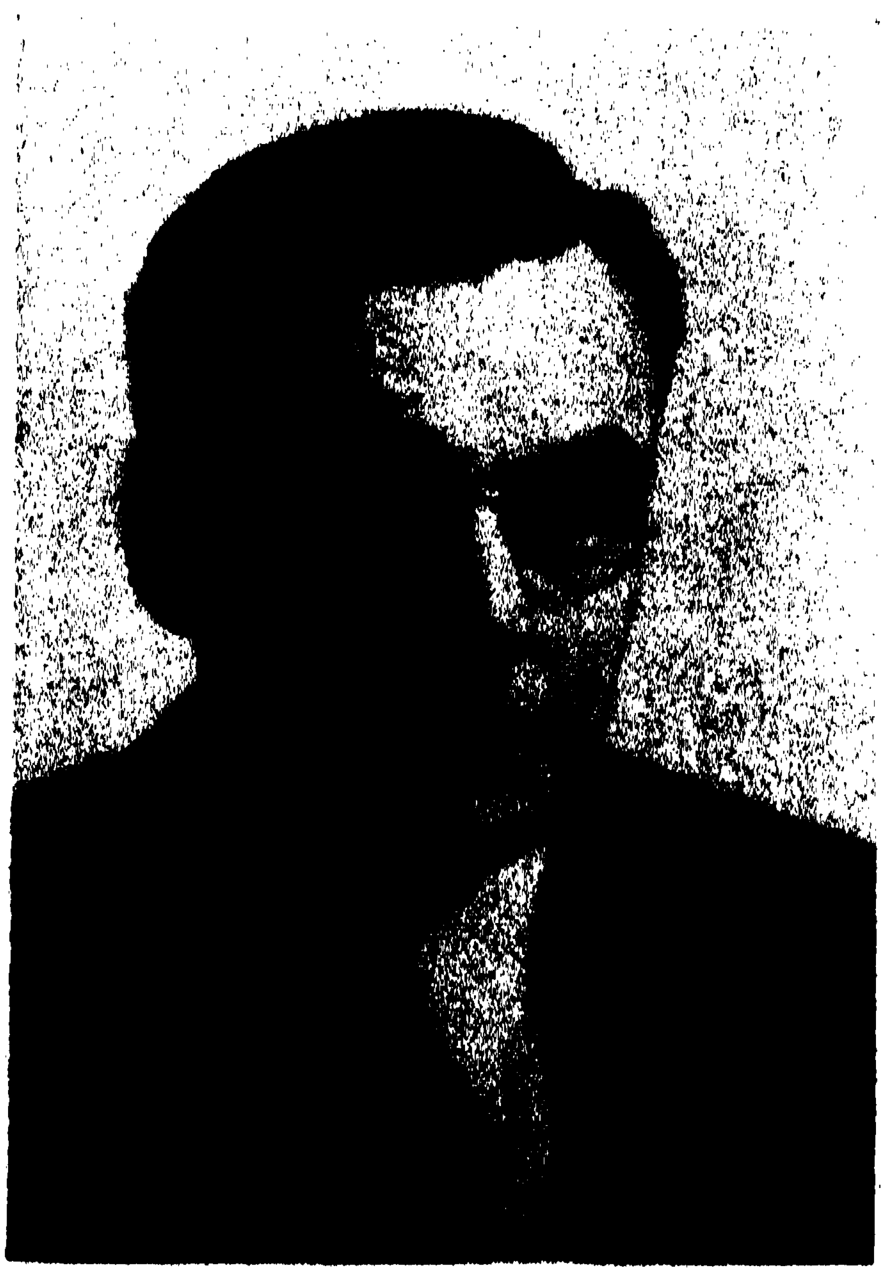
ALBERT F. WOODS

known and their relationships not suspected. I am told that in his later years he said that his failure to discover the cause of "peach yellows" was the greatest disappointment of his life.

Albert F. Woods was the next American worker to attract our attention, and he will be remembered as the originator of the enzyme theory. He was influenced by the studies on enzymes which were attracting so much attention at that time. He advanced this theory as an explanation of the cause of tobacco mosaic. This theory was very generally accepted at that time and for several years. Although this theory has very few advocates at the present time it was a great stimulus to research. Very recent studies on the chemistry of virus diseases by Vinson and Petri (1927–34), Barton-Wright and McBain (1933), Stanley (1935–36) and others have again brought this theory into some prominence. In this connection it is interesting to know that Hunger (1902–08) and Baur (1904–09) made studies on the

HARRY A. ALLARD

causal agents and that both came to the conclusion that these agents were nonliving and that they increased in amount in the cells of the host plants.



JAMES JOHNSON

Woods also made inoculation studies and was the first to demonstrate that tobacco mosaic would attack Petunia. He was the first to report mosaic on *Phytolacca decandra* and tomato. He also published (1897) a paper on a disease of carnation known as "stigmonose," which was probably a virus disease, and called attention to the aphis and other insects associated with it in a causal way. In the same year he published a report on the Bermuda lily disease, which is now known to be caused by a virus.

Harry A. Allard is the third American in my list of pioneers. His studies were almost entirely on the mosaic disease of tobacco. He made many cross inoculations and was the first American to make studies on dilution and filtration of the sap of diseased plants. He also studied the malformations of the flowers of mosaic tobacco plants. He rejected the en-

zyme theory of Woods, but believed that the disease was due to an ultramicroscopic organism. He appears to have been the first to suggest that some diseased plants were symptomless carriers, a fact which did not attract much attention until Nishimura published his paper on *Physalis alkekengi*. He followed the suggestion made by Clinton and demonstrated that an injury to a healthy plant was necessary before it could be infected by juice applied on the surface and that washing the hands of the laborers who were working with plants would remove the active agent and prevent much of the infection. The series of papers published by Allard became the foundation of much of the work that was to follow.

James Johnson was the next American to attract attention as a pioneer by his research studies and will be remembered for his experimental work on the effects of temperature on the symptoms of virus diseases. Some of the other early workers had made studies on the influence of environmental factors on these diseases, but the methods were not nearly so satisfactory as those used by Johnson. His studies became the basis of much of the work by other students of this subject.

It is very interesting to note that six of these pioneers studied the mosaic disease of tobacco, a disease which is still the subject of much important research work. One studied diseases of the peach and one studied diseases of the potato.

There were several other research workers who were studying virus diseases during this period and the following period who should probably be classed as pioneer workers. Some of them made contributions and others made observations and suggestions which have stimulated studies by others.

W. A. Orton was a pioneer in the study of the virus disease of potatoes and laid the foundation for much of the experimental work of more recent investigators. His studies consisted primarily of field observations, but he stimulated research by other workers. He discovered the mosaic disease of potatoes in Germany in 1911 and upon his return to America found that the disease was abundant in his own country. His influence was very evident in both America and Europe.

George P. Clinton's early work on tobacco was not extensive but was basic. The ease with which tobacco mosaic could be transmitted from plant to plant was known long before he began his studies, but he was probably the first to suggest that there was some connection between bruising of the glandular hairs and the transmission of the causal agent and that requiring the laborers to wash their hands with soap and water would remove the active agent and reduce infections in the seed beds and fields. This was confirmed by Allard, who demonstrated that ordinarily the disease was not transmitted unless the healthy plant had been subjected to slight injuries. He appears to have been the first to demonstrate the transmission of mosaic between tobacco and tomato.

This paper would be incomplete if we did not mention the pioneer studies on the transmission of the viruses by means of insects. The first proof of transmission of insects comes from Japan and the studies were made by Hashimoto and Takata (1894–96) on the transmission of the stunt disease of rice by an insect now known as *Nephotettix apicalis*. The next pioneer studies were made in America by Ball, Adams, Shaw, Townsend, R. E. Smith, Boncquet and others over a period extending from 1906 to 1917. A more complete discussion of the studies by these workers will be found in a paper in this journal for February, 1937.

Much important work has been done since 1920, and our knowledge of the subject has increased very rapidly. The next few years will undoubtedly bring forth a large number of important papers and may change our views on the viruses and probably on the characters of the simplest forms of life.

THE FAT OF THE LAND

By Dr. B. W. KUNKEL
PROFESSOR OF ZOOLOGY, LAFAYETTE COLLEGE

It is more than a poetic fancy that "all flesh is grass," as the prophet of old exclaimed, for the nutrition of all animals is derived from the green plants and can be traced to the process of photosynthesis. From the amoeba to man and the mammoth there is a complete dependence upon the products of green plants. Every bit of energy which they exhibit is the result of the oxidation of fuels produced by green plants. Besides this they furnish also the complex building materials necessary for growth and repair. It is the chlorophyll of the green parts of plants which absorbs radiant energy of the sunlight and transforms it into the energy of complex chemical compounds. This is the familiar process of photosynthesis. It is not a highly efficient process, for only about 2 per cent. of the radiant energy reaching the plants can be recovered from them by oxidation of the products of photosynthesis, and yet there is no energy lost—the rest simply warms the surroundings and is radiated into space.

The question I wish to discuss is: How much "grass" can be grown on a unit area; what is the maximum productivity of an acre in terms of food for man?

If we go back far enough in the world's history we find that there were no animals but only bacteria and green plants. The green plants represented a great advance over the bacteria because they were able to tap stores of energy which were locked against the bacteria and were well-nigh inexhaustible. The evolution of chlorophyll enabled these plants to absorb energy from sunlight and retain it indefinitely in the form of complex starches, cellulose, etc. From that time energy began to accumulate in these complex chemical bodies. The evolution of animals represented a further step in advance, for these creatures utilized the concentrated stores of energy synthesized by the green plants, oxidizing the proteins, carbohydrates and fats. They also were relieved of the complex process of manufacturing amino acids as a first step in the building up of protein. Thus, the animals digest proteins to amino acids and then pile these building stones in to new and individual patterns of protein and oxidize the fuels which were laid up by the plants.

Indeed, the whole evolutionary process, from the earliest appearance of life, has been to appropriate more and more energy of one kind or another; so that it can later be expended in heat, motion or other kind of kinetic energy more abundantly.

The growth of the blade of grass upward and its root downward, the laying down of layers of limestone by the coral polyps, the lengthening of the muzzle and the limbs of the ancestral horses, the cerebration of the philosopher and the labor of farmer and miner are all concrete illustrations of the thirst for energy exhibited by living things. In the last analysis all the activities of living things can be referred back to this demand for solar energy, for even the reproductive urge is for the purpose of increasing the number of absorbers of solar energy.

The most economical path by which solar energy is taken up by animals is directly from green plants, for it is obvious that when one animal feeds upon another animal it secures only the quantity of energy which is present in the

body of its prey at the moment, the great bulk of the food consumed by the prey has already been oxidized in the life processes, and the products of the combustion have been discharged into the great outside world and are lost so far as the feeder is concerned. These waste products in part may be ready to be resynthesized at once by the green plants; namely, the carbon dioxide and water. The nitrogenous wastes, on the other hand, must be acted upon by a variety of bacteria before they are again available as food for the green plants. These bacteria are the organisms which cause rotting of protein and the putrefaction of the excreta of the body. They oxidize vast quantities of these complex organic compounds in order to liberate energy for their own activities.

At the same time that it may be more economical to utilize the substance of plants directly for fuel than indirectly from the bodies of other animals, the physiological economy of the human body is probably served best by a mixture of animal and plant material in the diet. As will be seen later, however, this is very uneconomical of land. This wastefulness of the original solar energy falling upon a unit area may be illustrated best by following the course of the diet of the Eskimo to its origin. The Eskimo lives largely upon seal meat. The seal feeds upon fish, the fish upon snails and other invertebrates and these in turn upon seaweeds. As a growing child eats its own weight every ten days and the adult eats nearly four pounds of food a day or between 2 and 3 per cent. of his body weight a day it is evident that the Eskimo must consume many seals in the course of a year to keep going; certainly, while growing he must consume upwards of five pounds of food in order to increase his own weight one pound. Although the experiment has not been actually made to determine how much food must be consumed by the seal to gain a pound in weight, it must be essentially the same—that is, the five pounds of seal is obtained from twenty-five pounds of fish. Although the fish does not have to maintain a body temperature considerably higher than its surroundings, it may not have to consume as many pounds of food in order to gain a pound in weight. This estimate is so close to the maximum power of converting food into flesh exhibited by the prize swine which have been developed by careful selection (three pounds of food for one pound in body weight) there may be justification in retaining this ratio. The twenty-five pounds of fish therefore represent 125 pounds of shrimps, and this amount of shrimp required five times as much algae for their upbuilding. Thus each pound of Eskimo by this circuitous route of obtaining plant material is at the cost of 625 pounds of algae. This very wasteful food cycle is one of the reasons why the Arctic regions are incapable of supporting more than their sparse population. The population of Iceland is only about two per square mile for the whole area or one to 320 acres. This is not, however, a perfectly fair statement, for the Icelanders are not agriculturists. They are largely fishermen, getting most of their food from the surrounding water. But even in the Belgian Congo, where the solar energy is almost a maximum, there is an estimated population of only about one to sixty-four acres in contrast to the United States, where there is a density of population of one to fifteen acres. The sparse population of backward parts of the world is to be explained partly by the fact that man is able to utilize only a very small portion of the vegetation for food. The whole practice of agriculture, indeed, is the replacement of useless or noxious organisms by useful ones.

Whether the agricultural phase of

civilization is sooner or later to be replaced by the factory phase in which foods will all be processed or synthesized under cover in controlled climates and under controlled conditions of all kinds, is a question. It is one of the intriguing problems of biochemistry to synthesize carbohydrates from carbon dioxide and water without the agency of living plants and possibly utilize a larger proportion of the radiant energy of sunlight than the green plants do.

The problem of determining the supporting power of the earth is a difficult one. At the present time the population of the earth is about 1,800 million and the density of population is approximately one person to nineteen acres. This, however, shows us nothing about the real supporting power of the earth, because actually the density of population varies greatly and many parts of the earth are incapable of supporting any human beings. Here in the United States the density of population is one to sixteen acres; in Australia it is only one to 320 acres. The amount of arable land is variously estimated. Sir George Knibbs regards one half of the land area of the world as either too rocky or mountainous or dry or cold or occupied by roads and buildings and cities so that possibly sixteen billion acres may be regarded as arable. East estimates only 40 per cent. as arable or about thirteen billion acres. That is to say, there is enough arable land to allow each inhabitant of the earth from about seven and one fourth acres to nine acres upon which to raise his food and clothing. This, again, is not highly enlightening, for a considerable quantity of food is taken from the forests, the semi-arid grazing lands and the waters of the globe.

Here in the United States the density of population is somewhat greater than that of the earth generally. In 1918 (Year Book of the Department of Agriculture) O. E. Baker and H. W. Strong estimated that only about 413.2 million acres of the total land area of the United States of 1,903 million acres are improved. But these supported a population of about 106 million at the time or one for a little under four acres. This, however, does not take into account the population supported by cattle grazing over the unimproved prairies which cover a vast area in the west, where the rainfall is too sparse to permit an abundant growth of vegetation which would repay the expense of cultivation. East, in his "Mankind at the Cross Roads," estimates that the improved land may be increased, when the population is sufficiently pressing, to 800 million acres. The rest of the 1,903 million acres not devoted to crops includes 360 million acres of woodland and forest, 425 of cattle ranges, 238 of desert and eighty of roads, cities, railway tracks, etc. In addition to a population of 320 million which may by somewhat improved methods be supported on the cultivated land, one man per two and one half acres, East estimates that grazing land will support one man per one hundred acres or a total population of four millions, and the forest and woodland can support one man on fifty acres or seven million in all. The capacity of two and one half acres to furnish food and raiment for one person was arrived at by East on the basis of the intensive agriculture of some of the European countries. He calculated that pre-war Germany cultivated two acres for each man supported, France 2.3 acres and Belgium 1.7 acres.

The ratio of arable land to population in other parts of the world is very diverse, as the figures in Table I indicate.

These figures, of course, do not mean that the menu of the Japanese is raised on a third of an acre. There is much food imported which is paid for by the exports of manufactured goods, and a

TABLE I

Country	Acres per inhabitants
Canada	28.9
Argentina	18.5
Russia	4.2
United States	3.3
Denmark	2.2
Roumania	1.8
Sweden	1.5
France	1.3
Italy	1.27
Germany	1.1
China	0.76
Netherlands	0.69
England	0.63
Belgium	0.56
Japan	0.36

considerable part of the food is taken from the sea.

The determination of the relative efficiency of the agriculture of the different countries requires much calculating. One of the best indices is that used in Table II, which is determined on the basis of the average production of the six principal crops—wheat, oats, barley, rye, corn and potatoes—over a series of years. Each crop of each country is weighted in accordance with the percentage of acreage devoted to each crop and the several percentages are then added together. The relative productiveness of the farms of the principal countries is expressed in Table II.

TABLE II

Belgium	221
Holland	190
Great Britain	177
Germany	169
Denmark	168
Japan	137
Canada	136
Chile	136
Sweden	128
France	123
Austria	120
Hungary	113
United States	108
Italy	96
Rumania	94
Spain	93
Argentina	75
Russia	71
Mexico	52

In Bulletin 987 of the Department of Agriculture the relative efficiency of agriculture in the several countries may be seen by the average yields in bushels per acre of the crops listed in Table III.

TABLE III

	Wheat	Corn	Beans	Barley	Potatoes	Rice
United States	14.3	26.3	10.1	25.6	92.7	38.4
Great Britain	31.8	...	27.3	32.9	213.9	...
France	16.5	16.8	13.3	21.4	99.0	...
Italy	15.0	23.7	3.3	17.4	71.1	46.5
Japan	22.6	26.6	14.2	25.0	151.6	51.8

Another comparison of the agricultural capacity of different parts of the earth may be made by dividing the total yield of the principal crops by the total area of the country. The figures for Great Britain and Germany were compiled by Sir Thomas Middleton on the authority of E. H. Starling in "The Feeding of the Nations" (1919). The figures for the United States are taken from the statistics in the *World Almanac* and are for 1925 (Table IV).

The differences in the yield of different countries are to be explained, of course, by the general agricultural practices, such as the choice of seed and selection of cattle, the quantity of fertilizer applied, the amount of water available to the growing plants, the control of pests, climate, etc. Social and economic factors are involved, including the cost of land, cost of labor, etc., but these factors will have to be passed over at this time.

The figures thus far presented show simply the present results of agricultural practice over large areas and with all degrees of intelligence and skill. The application of the same degree of skill and the same efficiency which is applied to large scale manufacturing plants would without doubt result in the reaping of much larger harvests per acre than are represented by the average figures just cited.

In order, then, to determine the maximum yield of foodstuffs per acre, it is necessary to consider some of the princi-

TABLE IV

	Great Britain	Germany	United States
Persons fed per acre of cultivated land	0.4–0.5	0.7	0.12
Wheat (per acre)	300 lbs.	660 lbs.	43.80 lbs.
Potatoes (per acre)	220	1100	21
Meat	80	90	
Milk	350	560	
Sugar	negligible	550	
Corn			156

ples of plant physiology which limit soil productivity.

In the first place, the plant physiologist and agrobiologist have established the fact that a particular strain of plants can produce a definite yield beyond which all the nursing and feeding and culture can not push it. It is the same principle which we see all about us among the animals. There is a limit of growth which can not be surpassed in spite of effort. The roots of the plants by their hereditary qualities will allow certain salts to pass into the plant in certain proportions, regardless of the proportions of those salts in the soil. Corn and wheat growing side by side in the same soil have a very different composition, and use very different amounts of mineral salt and will stop growth at a particular season or when they have reached a certain size.

The productivity of an acre, therefore, depends in the first instance upon the character of the seed sown and the stock bred. What can be achieved further in this direction is entirely problematical. The story of selection of wheat by crossing different strains and so combining the desired qualities of various strains in a single one is romantic. As a result of a comparatively few years of experimenting the Marquis wheat was selected so that it became possible to grow that cereal over hundreds of thousands of acres in Canada which hitherto had not been available for this purpose on account of the short growing season and increased the yield nearly 30 per cent. The improvement of fruit trees and milk producers, fat producers, meat producers and egg producers in the past thirty years by the application of the Mendelian principles of heredity is well known to every one.

Of the external factors which influence the growth of plants the only ones which need to be considered at this time are water, nitrates, phosphates and potash. It is fully realized that these are not the only necessary substances for plant nutrition. Only recently the addition of sulfur as gypsum to the soil increased the yield of alfalfa fivefold, iron sulfate sprayed on the leaves of pineapples in Hawaii has made the fruit grow much more luxuriantly, and the addition of copper in very minute quantities has made certain peat lands most productive. But the only compounds which have to be added in any considerable quantity are the nitrates, potash and phosphates and on certain soils lime. An excess of one of these constituents can not compensate for a deficiency in another. If the soil is provided with an excess of fertilizer but lacks sufficient water the amount of growth is determined by the amount of water; or if there is an abundance of water and nitrates and potash but insufficient phosphate the amount of growth is limited by the amount of phosphate. The plants are not able to make substitutions for these substances as the manufacturer is frequently able to do when some one raw material is curtailed and his supplies of this are insufficient to permit of his usual production.

Another interesting relation between the amount of growth and the amount of materials in the soil used by the plants is that equal additions of the proper proportions of these substances do not yield correspondingly large amounts of plant substance. Each successive addition of a unit of fertilizer and water yields less and less until there is no further addition

to the yield. About one half of the amount of nutriment necessary to give the maximum yield of a certain type of plant will, as a matter of fact, give about 90 per cent. of the maximum. In other words, it takes as much fertilizer to add 10 per cent. to a 90 per cent. crop as it required to obtain a 90 per cent. crop. If the soil is not to be depleted, therefore, by the removal of crops which eventually find their way to the sea, it is necessary to keep the soil "filled" with nitrates, potash and phosphates, some 1,115 pounds of nitrogen, 441 pounds of potash and 267 pounds of phosphate to the acre. The nitrogen may be added by the fixation of atmospheric nitrogen by bacteria of several species, one of which forms nodules on the roots of the leguminous plants. It is this process of rotating crops with leguminous species introduced periodically which has maintained the nitrogen of the soil on many acres over long periods. There is a twofold necessity for water in the growth of plants. Not only does water make up a large part of the growing plant, but it also furnishes the means by which the salts are transported from the level of the roots to the leaves, where they are brought into relation with the sugars manufactured by the leaves and synthesized into proteins, the most individual and abundant constituents of the living substance itself. In general, it is found that in order to build up one pound of dry plant substance, some 300 pounds of water must be evaporated through the leaves. About 3,000 tons of water or fifteen inches over one acre is evaporated during the growing season of a good stand of corn. By proper conservation of moisture, however, some very remarkable yields have been achieved with much less rainfall than fifteen inches. In 1932 there is a record of wheat yield of forty-eight bushels to the acre on a farm in North Dakota, following a series of four dry years when the water table was much lowered and the rainfall during the growing season was only 6.63 inches. In 1927 in a wheat-growing contest in Czechoslovakia when there were only twenty inches of rainfall, 1,070 farms produced on an average forty-six bushels of wheat to the acre, and one of them harvested 87.2 bushels to the acre.

It has been ascertained experimentally by the successive additions of the various fertilizing substances until no further growth is made that the maximum yield of the most effective plants known to-day are able to utilize approximately 318 pounds of nitrogen per acre. The quantity of carbon is not apparently thus limited, for plants in which there is a low percentage of nitrogen are produced in larger quantity on a unit area than those in which there is a high percentage of nitrogen. The yield of 318 pounds of nitrogen per acre may be termed the per-ultimate yield. It is possible that other races of plants may be developed which are able to build up more nitrogen, but this is by no means certain. It must be borne in mind also that to obtain the per-ultimate yield requires the addition of twice the quantity of water and fertilizer necessary to produce 90 per cent. of this.

It is only rarely in practice naturally that water and fertilizer are supplied in the proper amounts to yield anything like a maximum crop. The expense is generally prohibitive, except for laboratory experiments. Experiments have been made in this country, however, under field conditions which have yielded in some cases crops as abundant as have ever been obtained in the open in any part of the world. But because of the practice of extensive rather than intensive cultivation, the average yield of the farms of the United States is only about 12 per cent. of the highest yield known.

In the midst of the last war when a shortage of the principal foodstuffs was

imminent, the U. S. Bureau of Plant Industry carried out a number of experiments on a large scale in order to determine to what extent the production of food might be increased most economically of man power and machinery. Some of the plots were only one acre in extent, but others were as much as eighty or one hundred acres. They were located in Washington, California, Colorado, Virginia, Kansas, etc. A comparison between the best yields of the six principal crops with the average for the years 1927–30 over the whole country and with the highest known yield in any part of the world is instructive (Table V).

TABLE V

Crop	Average	Highest yield in the expt.		Highest known
Wheat .	14.4 bush.	117 bush.	8 × average	122.5 bush.
Barley .	24.1	122.5	5	122.5
Oats ...	30.4	183.7	6	245.7
Rye ...	12.8	54.4	4½	54.4
Potatoes ..	114.9	790	7	1156
Corn ...	25.5	174	7	225

From the results of these experiments, and knowing the actual production of these crops in 1927–30, it is obvious that the same yield might have been obtained from the following acreages: wheat, 5.26 million, barley 2.29, oats 5.20, rye 0.87, potatoes 0.30, corn 9.16 and sugar beets 0.21, a total of 23.29 million acres. This is an area somewhat less than that of all the farms in the state of Colorado alone. But as no allowance has been made for accidents from insect plagues or plant diseases or vagaries of weather some margin of safety should be provided for. If 30 per cent. is allowed for these inroads, the acreage is increased to 33.2 millions of acres, which is less than the total area of all the farms in the state of Kansas. This increased intensity of agriculture would, naturally, bring about a great reduction in the number of farmers and a great deflation of farm values with correspondingly great social and economic repercussions. These figures, however, give some hint of what may be expected from the more general application of thoroughly scientific agricultural methods.

As indicated above, the production of starch and sugar is much greater than that of protein. Only about 15 per cent. of the protein molecule is nitrogen, so that the per-ultimate yield of 318 pounds of nitrogen per acre represents about 2,200 pounds of protein, while in a corn crop 2,200 pounds of protein is associated with over 9,300 pounds of carbohydrate in the seeds, stalks and leaves. An acre of potatoes yielding the maximum in the Bureau of Plant Industry experiment cited above, 790 bushels, produces 6,542 pounds of carbohydrate in the form of starch; the maximum yield of sugar from sugar cane is 20,000 pounds a year. The highest yield of protein obtained from the maximum corn crop in the experiment mentioned above is about 2,000 pounds, but less than 800 pounds are digestible because of the fact that it is largely surrounded by indigestible cell walls of cellulose. A maximum crop of onions, 40,000 pounds to the acre, contains 760 pounds of protein, and as will be apparent presently when we look into the requirements of a man for a year eating approximately the kinds of food which he is accustomed to in the United States and making due allowance for variety of food, the adequate supply of the vitamins, etc., the problem of providing protein becomes more difficult. It is necessary to provide an abundance of nitrogenous food for the domestic animals which furnish man with meat and milk and eggs. These are exceedingly important sources of the proteins which man consumes and, as will be seen later, require a large area for their production. There are several ways by which it is possible to increase the amount of pro-

tein produced by an acre. First, the growing period may be shortened so that several crops might be raised in place of one. This is hardly practicable, however, because it entails raising the plants in an artificially controlled illumination and artificial climate with high temperature during the winter months. It has only recently been discovered that the length of day has an important effect upon the maturing of a variety of plants. In one experiment reported in the Year Book of the Department of Agriculture for 1920, soybeans, which are an excellent fodder for cattle, were germinated on May 17 and kept in a dark greenhouse except for seven hours daily, when the plants were moved out of doors. These plants blossomed in 26 instead of 110 days, as did the controls. It is in this way possible to get the fruit in a much shorter time than normal and so telescope the successive crops, as it were.

A more practical device depends upon the fact that the absorption of nitrates and the building up of protein does not go on at a uniform rate during the entire life history of the plant. Much more than half of the nitrogen is taken up in the first half of the growth period. Later, while the carbohydrate is being increased and the plant may be increasing its dry weight considerably, the protein is simply shifted from one part to another. As the seeds ripen there is a great concentration of protein from the leaves in the seeds. We may not find the traditional menu of Nebuchadnezzar practical for ourselves, but by feeding to cattle the partly grown products of the soil it is possible to increase the potential yield of protein during one season several fold. Instead of reaping the golden grain it is more economical from the point of view of the production of protein to keep the grain fields closely cropped like a well-kept lawn, the clippings being cured and fed to the cattle. The use of ensilage by the dairy farmer is simply the practical application of this principle. In one experiment on a mid-western farm, wheat was planted during the second half of August and clipped from eighteen to thirty-one days later just before the stalks showed "jointing." On the best soil from 1,000 to 2,000 pounds of dry hay testing 30–40 per cent. protein were obtained from an acre. At this rate, the same planting may be clipped several times before freezing and again several times in the spring. On May 15 the wheat was plowed under and the field was planted in Sudan grass and yielded one ton of dry matter every ten days until wheat-planting time. The total yield for the year by this treatment was 7 tons of wheat and Sudan hay containing 4,000 pounds of protein per acre. Obviously this method of culture has great significance from the point of view of the dairy man and stock raiser, for the seven tons of hay, reckoning only 13 per cent. digestible protein and 66½ per cent. digestible carbohydrate, is the equivalent of 233 bushels of wheat or 250 bushels of corn, about five times the nutritive value of ordinary corn and wheat land cropped but once a year.

There is still one other way by which the yield of protein from an acre may be increased, although this may not be entirely practical with the present technical arrangements. The microscopical colorless plants like the yeasts are composed of protein to the extent of 50 per cent., which they synthesize from carbohydrates and nitrates or ammonium salts. By growing yeast in solutions of sugar to which nitrates are added a very rich protein food to supplement fodder is possible. In this way one pound of sugar may produce one half pound of yeast. Thus a pound of sugar may give rise to one fourth pound of protein in the form of yeast. In addition alcohol is produced, which has a high commercial value

for its own sake. There are strains of sugar-cane which have recently been bred which yield, according to Dr. William Crocker, of the Boyce Thompson Institute, fifteen tons of sugar to the acre or through the action of yeast three and three fourth tons of protein.

Allowing an annual consumption of eighty pounds of protein, this would furnish enough for ninety-three men. The growing period for the cane, however, is eighteen months rather than twelve months, so that the number of men which could live on this protein would have to be reduced to about sixty-two or 39,680 to the square mile. In addition to eighty pounds of protein, however, a man must consume sufficient non-nitrogenous food to yield 851,200 calories per year, for an ample energy requirement for a year is 1,000,000 calories, of which the eighty pounds of protein yield 148,800. The 851,200 calories might be obtained from 458 pounds of dry carbohydrate. The protein and energy requirements for the year would thus be obtained for one man on 0.039 acres or about twenty-five persons to the acre.

But this heavy yield of potential energy from an acre planted in sugar-cane with fifteen tons of sugar does not tell the whole story of what the sugar-cane actually builds up, for there is also a residue after the extraction of the sugar of 5.3 tons of cellulose. Twenty and three tenths tons of carbohydrate are therefore synthesized to the acre, in the growing cycle of 540 days or 75 pounds a day. This amount of plant tissue represents 139,500 calories. It has been calculated that on the 40th parallel of north latitude between May and October the solar energy reaching the earth is 30×10^6 calories, so that this plant is utilizing less than a third of 1 per cent. of the solar energy, not a highly efficient engine. The diet of yeast and sugar is, of course, a highly impractical sort of diet. While starvation might be avoided for a short time on this limited fare there would soon come a revulsion of appetite and serious digestive disturbances and nutritional disorders. The diet would lack flavor, variety and bulk and certain vitamins. The problem of adding artificial flavors, vitamins and bulk which would render the diet satisfactory for an indefinite period is by no means insuperable. It is noteworthy that a few years ago at the Cornell experiment station there were slaughtered two sheep which had been reared entirely upon artificial foods, casein, cellulose, starch, vitamins and salts, that is, on foods which had been concentrated and processed so that not a single blade of grass or kernel of corn had been eaten by these sheep, which were apparently in a perfectly healthy condition.

It may not be an ideal of life to reduce dining to the rigorous limitations indicated in this program. How many of us would submit to such a restriction of tickling of the palate is to be determined only by the psychologists. Possibly by proper conditioning from early childhood or infancy we might remain as healthy and happy as the sheep which were fed entirely on synthetic and processed foods. Incidentally, we consume a good deal of thoroughly artificial, processed food even to-day and prize it highly. Cane sugar, chocolate, cocoa, casein products, milk powders, gelatin, olive oil, corn oil, cotton seed oil, to say nothing of flour itself and the various bran preparations which are widely advertised and attractively packed in order to combat constipation, are all highly artificial foods to which most of us have become thoroughly accustomed and of which we are inordinately fond. Twenty-five persons supported on an acre of ground with a very small amount of laboratory or factory space for the synthesis

of the accessories of the diet may not be so far distant a dream, after all.

In order to remove this discussion from the realm of the theoretical but by no means impossible, let us look at this matter of human diet from the point of view of our more normal food habits. As already indicated, eighty pounds of protein a year and approximately one million calories are needed by an average person not engaged in hard labor. About one half the calories should come from the so-called "protective" foods, milk and dairy products, vegetables with their salts and vitamins, fruits, eggs and meat. The different proteins which may be isolated from the naturally occurring foods vary greatly in their ability to promote growth and supply the wear and tear of the adult body. It is for this reason that a variety of foods becomes a practical necessity, unless the kind of protein is very carefully selected. Fats of certain kinds have to be supplied, not only to regulate the digestive processes which are adapted to a certain amount of fat, but also to supply certain of the vitamins which occur only in association with them.

Those of us who do not give a great deal of thought to our diet and who eat what is set before us and take it all in the round of daily activities to eat three times a day, may not have a very clear idea of just what we consume in the way of foods purchased and grown on the farm. Some months ago there was published in Circular 296 of the U. S. Department of Agriculture a liberal diet which was supposed to furnish an abundance of the varieties of protein and the vitamins necessary for the maintenance of health for one man for a year. It calls for 1,874 pounds of food, including 77.6 pounds of protein and has a calorific value of 1,054,000 calories or 3.4 ounces of protein and 3,000 calories a day (Table VI).

TABLE VI
YEAR'S FOOD FOR ONE MAN

Foodstuff	Pounds	Pounds protein	Calories
Cereals	100	13.8	167,500
Milk	700	23	227,500
Potatoes	129	2.3	40,000
Root vegetables	46	6	15,750
Beans, corn, etc.	33	1.58	16,000
Leafy vegetables	142	2.89	15,340
Tomatoes and citrous fruits	110	.99	12,130
Fruits	292	1.67	69,405
Butter	35	.35	126,000
Lard and other fats	15	.00	62,650
Sugar	45	.00	83,600
Molasses	15	.36	19,370
Meat	149	22.39	164,540
Eggs	45	5.35	28,575
Fowl	18	2.3	5,310
Total	1874	77.59	1,053,625

That this is a liberal diet is borne out by the extensive experiments carried out by Atwater in Wesleyan University. For example, he found a group of Japanese students consumed each sixty-seven pounds of proteins in a year and 855,195 calories. A German physician consumed 90.4 pounds of protein for the year and 1,008,130 calories; American college students at student boarding houses consumed only seventy-two pounds of protein and 1,250,000 calories.

The calculation of the areas upon which these various foods may be grown is very simple mathematically, although the obtaining of the necessary data is rather difficult.

Let us consider the area necessary to produce the dairy products and meat. Figures from the book of E. H. Starling, "Feeding the Nations" (p. 85) show that in German agriculture before the war one acre was sufficient for the production of 560 pounds of milk so that the 700 pounds could be produced on 1.26 acres. On the basis of twelve pounds of cattle feed for the production of one pound of meat or milk and assuming the maximum production of feed of the experiments of the Bureau of Plant Industry referred to above, the same area is required.

Butter is one of the most expensive

foods but one which is quite important in the well-balanced diet. As one pound of butter is 85 per cent. fat and average milk contains 4 per cent. fat, it requires about 21.25 pounds of milk to make a pound of butter and 255 pounds of dry fodder to yield 1 pound of butter. To produce thirty-five pounds of butter therefore requires 8,925 pounds of feed. If the fodder has the richness of corn this can be raised on about .83 acres. The rest of the fats may be reckoned as by-products of the pork and other meats which are consumed and so would not require additional acreage to produce. The hen is not quite as economical a producer of human food as are the cattle. Probably the higher body temperature and the smaller size of the fowl with a relatively large surface cause more of the food to be consumed at the same time that a unit of growth or food products is being made. It takes about fourteen pounds of chicken feed to make a pound of eggs. For the sake of simplicity, if we reckon upon the use of wheat as the food of the hens, 630 pounds of wheat must be raised to produce the forty-five pounds of eggs; 0.11 acres will suffice for this. The eighteen pounds of poultry included in the diet requires an additional .045 acres.

One hundred and forty-nine pounds of meat, if it is that of young animals, are produced at an expenditure of 1,788 pounds of dry fodder. The flesh of steers costs much more in the way of fodder to produce, for after growth is attained the animal continues to feed without further increase in weight. If this fodder is represented by corn and corn stalks produced at the maximum American rate of 174 bushels to the acre, it can be produced on 0.09 acres.

The 100 pounds of cereal grains eaten in the year may be regarded as 5,850 pounds of wheat and may be had from an acre which has yielded 117 bushels; this requires only 0.017 acres. The 129 pounds of potatoes can be raised on an area of 0.003 acres, since the highest yields are 790 bushels or 47,400 pounds.

It is more difficult to arrive at an estimate of the area necessary to supply the 292 pounds of fruit called for in the diet. According to figures obtained from the Bureau of Agricultural Economics of the U. S. Department of Agriculture a good yield of apples under favorable conditions is 36,000 pounds per acre, so that the 292 pounds of fruit might be obtained from .008 acres.

Vegetables, which make up about one fifth of the diet in actual weight, may, for the sake of simplicity, be considered as made up entirely of tomatoes, which have a composition which is not far from the average of the more common vegetables, yielding 100 calories per pound. As 40,000 pounds of tomatoes have been raised on an acre in the United States, the 331 pounds consumed by a man in a year could be grown on 0.0083 acres.

Forty-five pounds of sugar and fifteen pounds of molasses may be obtained from either sugar-cane or sugar-beets. The former is more productive but can not be grown where there is danger of frost, so for the sake of making the self-sustaining farm in the latitude of the United States we shall obtain the sugar from beets. Sugar-beets containing 15 per cent. sugar may be grown to the extent of 42 tons to the acre. Although the molasses is a by-product from the crystallization of the sugar, for the sake of simplicity it may be added to the sugar as if it required additional acreage to produce. The sixty pounds of sugar could be grown on 0.0005 acres.

Combining the areas required for the different items of the diet, we find that a total of a little less than 2.4 acres is necessary for the support of one man for a year if the highest yields known in the

United States are obtained. Although the idea may be advanced that this does not allow sufficient margin of safety and that the figure is therefore misleading, it may be replied that the large area required for dairy products—2.09 acres—is obtained on the estimate that it requires twelve pounds of fodder to produce one pound of milk. This is simply an average and does not represent the maximum yields of selected herds. As a matter of fact the best milk and fat producers as a result of selection can produce about double the quantity of milk and fat so that the dairy products would require only half the area allowed in the above calculation and the entire acreage would then come to one and a third acres. So, too, the best swine gain one pound for every three pounds of food eaten, and as the dressed pork with the lard is approximately 60 per cent. of the live weight, it would take only five pounds of fodder to produce one pound of human food.

The social and economic consequences of this shrinkage of farm land are extremely far reaching. Part of the present plight of the farmer whose skill is insufficient to achieve the best results and whose products can not be economically distributed is tied up with the increasing efficiency of farms and the increasing capacity of man to produce food from the ground.

The displacement of the draught animals by the tractor has not only made unnecessary the product of 30 million acres of farm land formerly needed for energizing farm animals but has made it possible for one man to cultivate a vastly larger farm. As gasoline and oil reserves are drained more and more, the farmer may be called upon to devote more of his energy to raising sugar or other crops from which a fuel like alcohol may be obtained to run his tractors, which will be renewed year after year by the grace of the sun. Before the farm land has shrunken to the extent that has been indicated in the reduction of farm area necessary to feed a man, it seems highly probable that the cellulose of plants will be used more and more in the arts to take the place of building materials, plastics, etc., so that the farmer may be called upon to grow new crops which yield materials that will not be used for food. It seems very evident that because of the technical advance of agriculture the farm must become more of a large-scale productive unit in which a degree of efficiency comparable to that of well-managed manufacturing plants will be the aim.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]
WASHINGTON, D. C.

BEGINNING OF ENGLAND'S GREAT SCIENCE BODY

On these cooler fall days, when the man of the family trudges down the cellar to start the furnace, it is an interesting speculation to turn back time some three centuries and consider what might have been the fate of science if the homes of that day had had good heating plants that would have made houses cheery places in which to stay evenings.

As it was in the 1640's, private homes were, for the most part, poorly built, uncomfortable and cold. In contrast the taverns were the places of warmth and cheer. Thus in the snappy fall of 1645 it is not strange that a group of diners should meet regularly at the Bullhead Inn in Cheapside, London, to discuss and experiment in natural philosophy.

As Professor C. S. Slichter, of the University of Wisconsin, recently told the Mathematical Association of America, it was this group—called by Boyle the "Invisible College"—that in 1660 organized the "Visible College," which within two years became the Royal Society of London for the Improvement of Natural Knowledge.

Universities and colleges there were in the England of that time, but science got its British start through the Royal Society and not through Oxford or Cambridge, where Aristotle and the seven philosophies were safely, and all too contentedly, entrenched.

No hide-bound, long-bearded academicians were the new Royal Society members. Among the founders was a chemist, a physicist, a bishop, two peers and so on. Robert Boyle, Robert Hooke and Christopher Wren were names on the original roster. It published Sir Isaac Newton's famed "Principia." On the title page can be found "Samuel Pepys, President Royal Society, he printed it."

Yes, the versatile Samuel Pepys was indeed president of the Royal Society in 1684. This shows the Royal Society's broad membership whose charter—granted on July 15, 1662, by royal decree—is considered one of the greatest events in British history.

FEDERAL SURVEY OF SCIENCE RESOURCES

The science resources of the nation are coming under the scrutiny of a group of experts rallied by the National Resources Committee, just as other authorities have conducted inquiries into technological trends, population, minerals, production and consumption, land, water and public works.

Here we have working for the nation a "brain trust" worthy of the name, not only because its members are competent producers of arranged facts and ideas, but because they are engaged in blueprinting what may be our future.

The planners viewing our science resources work under a committee of nine, appointed three each by the National Academy of Sciences, the American Council of Education and the Social Science Research Council. Thus boundaries between the physical and natural sciences, the social sciences and education, which are man-made but nevertheless real, are in part erased.

A study of "federal relations to research" is being conducted on behalf of the Science Committee by a small staff directed by Dr. Stuart A. Rice, chairman of the U. S. Central Statistical Board. The inquiries and practical results of the now-extinct Science Advisory Board of 1933 vintage will be remembered. There is more accent on the social consequences in the present inquiries

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

and less consideration of the "pure" research so disdainful and yet so fruitful of our industrial revolutions.

The technological trends report of some months ago emphasized the extraordinary ability of the American people to invent new ways of doing things and to adopt mass production methods for putting new inventions into use. Soon to appear is a National Resources Committee report on population problems, directed by Dr. Frank Lorimer. It will consider whether we are conserving our human resources, how many people this land will have in 20, 50 or 100 years and what kind of people.

NEW TOOL FOR BIOLOGICAL RESEARCH

Scientists are just beginning to talk about it, but there is good reason to believe that one of these days the science of biology will be supplied with a new tool of discovery by its sister science of physics. The tool would be the bombarding of biological specimens with streams of swift-flying electrons and the observation of the pattern created by the electrons as they bounce back.

This technique—known technically as electron diffraction—has already been used by the physicists to study the crystal structure at the surface of metals and other solid crystals. To Drs. L. H. Germer and C. J. Davisson, of the Bell Telephone Laboratories, go the credit for the initial experiment in 1927.

Virtue of the electron diffraction method is that it permits studies on very thin films, which may be only a single molecule thick. Such films have importance in biology. While the diffraction of x-rays allows scientists to study large chunks of matter, the x-ray method falls down completely for very thin films of molecular thickness. And it is just at this point that the method of electron diffraction steps in and carries the burden.

The technical difficulties of using this possible new tool are mainly two; the difficulty of interpreting the results for the complex things which are commonplace in biology but rare in physics, and the difficulty of mounting the biological samples in the necessary apparatus. On this last point the trouble is that all operations must be carried out in a vacuum, and there is always the question of whether biological material remains unchanged in a vacuum.

It has been suggested that the biological samples might be frozen at liquid air temperatures and quickly inserted in the apparatus, but this presents additional complications which are typical of the difficulties that must be overcome.

MARS AN ARID PLANET

It was once the fashion to suggest that the ever-curious marks on the planet Mars were due to some human-like agency; a race of Martian men who had constructed gigantic ditches or canals. Then when the markings were found to change with the Martian seasons the hypothesis was brought forward that the markings were, perhaps, plant growth and other vegetation.

But even this last suggestion that the canals on Mars were merely great straight stretches of plant growth (possibly like the Mid-western shelter belt may be a century hence) has had its difficulties.

One of the most recent of these troubles comes from the great Mt. Wilson Observatory of the Carnegie Institution of Washington, where it has been found, from a study of the light spectrum of Mars, that the ruddy planet has little, if any, water vapor present in its atmosphere, at least in the equatorial region where the observations were made. An outside limit for water vapor in Mars' air would be about 5 per cent. of that present in the earth's atmosphere.

The first months of 1937 saw the planet Mars come to one of its nearer approaches to the earth. Astronomers at Mt. Wilson decided to use the great 100-inch diameter telescope and special photographic plates to test, again, the

question of the presence of water vapor on Mars. Director Walter S. Adams and Dr. Theodore Dunham, Jr., slowly turned the huge telescope in the direction of the earth's companion planet and for six hours allowed the faint light to strike their photographic plates.

Unfortunately for the plant growth hypothesis of the origin of Mars' canals, little if any water vapor was found. The possible way out of the dilemma, however, would be to have the Martian plants consist of some form of cactus that needs but little water and could live in the arid region corresponding to Mars' equator.

BRAIN WAVES HAVE AN UNKNOWN DESTINATION

The human brain is constantly beating out a rhythm of brain waves. In its own unrecorded code, the seat of man's intelligence is tirelessly sending signals.

Where do they go? What happens to them? That is the question raised by modern psychological research. The brain used to be thought of as a sort of telephone exchange where messages sent in from the body's outposts, the eyes, ears, mouth, nose and fingers, are connected with the muscles they direct. Now it is known that the brain is more than a message center. It is also a reservoir of energy—a starting point for spontaneous activity.

The brain waves are the electrical accompaniments of this physiological activity, having its first beginnings in the brain itself. But we are used to thinking of electrical impulses as traveling. Signals are not only sent out but usually also received. Messages have a destination as well as a point of origin. What is the destination of the brain's messages? No one knows.

Tests were recently made at the University of Iowa to find out whether they travel to the outer limits of the nervous system. Similar electrical rhythms had been observed in the finger-tips. It occurred to the Iowa scientists that this might be a reverberation of the brain waves. Under the direction of Drs. Lee Edward Travis and Charles N. Cofer tests were made.

Although the frequencies of the finger-tip waves are practically the same as those of the brain waves, the patterns do not correspond. Some of the subjects had large and regular, while others had small and irregular brain waves. The finger-tip waves do not follow the brain waves in this respect. The brain waves might be interrupted or change without any corresponding change in the finger-tip rhythm. They are not the same. The secret of the brain wave destination remains unsolved.

ANIMALS OF COOLER REGIONS LARGER THAN WARM-LAND KIN

Science now provides support for the common observation that races living on mountain heights or in northern latitudes are on the whole larger than those living at low levels and farther south. This opinion, usually held only as regards human beings, is extended to include animals as remote from man as birds and insects, in studies made by Professor Theodosius Dobzhansky, of the California Institute of Technology.

Professor Dobzhansky bases his conclusions both on studies of specimens collected in the field and on the growth of a number of different kinds of organisms in the laboratory.

Races of mammals inhabiting cooler regions, although they may be in general larger, have shorter body appendages (tails, legs, ears) than races of the same species from warmer regions. Among birds the same is true for the relative lengths of beak, legs and wings. Races of mammals and birds and some invertebrates living in cooler climates are larger in body size than races of the same species in warmer climates. In mountain countries races from higher elevations are larger than those from the lower ones.

Professor Dobzhansky also exposed pupating butterflies from Central Europe

to both cold and heat. The heated pupae developed into butterflies resembling those of the same species found in Syria and other Mediterranean areas; the chilled ones produced insects more like those of northern Scandinavia.

The experimenter points out a possible physiological usefulness in these phenomena. In cold countries short ears, legs and tails are an advantage because they radiate less heat; in warm countries such economy is not so imperative. The larger body size, on the other hand, is correlated with a relatively smaller body surface—again effecting an energy economy.

DEER, LIKE HUMAN BEINGS, THRIVE ON VARIED DIET

Deer, like ourselves, seem to thrive best when they get a variety of things to eat. Again like ourselves, they face the problem of possibly harmful monotony in diet most acutely in winter, when the supply of "greens" offered by the woodlands is at its lowest.

In an effort to learn the absolute minimum on which deer can survive in winter, L. A. Davenport, of the Michigan Department of Conservation, kept a considerable number of the animals in separate feeding pens last winter. His control group received "browse" of varied types—abundance of white cedar and other evergreens and plenty of bud-bearing twigs of broadleaved trees like oak and maple. Deer in the other pens got only one kind of browse for each experimental group. One group received only white cedar, another oak, another maple, and so on.

The animals on a single-ration diet fared poorly. They all lost weight, and some of them died. The control group given the mixed diet, on the contrary, throve as well as they would have in the open woods.

Mr. Davenport's experiments show the great importance of white cedar or arbor vitae as winter browse for deer, at least in this part of the country. The deer having free choice of diet made white cedar about 80 or 85 per cent. of their total feeding, and the rest a mixture of hardwood buds. And the group fed on white cedar and nothing else got along decidedly better than any of the other deer kept on the other "monotony rations."

It would appear therefore that, at least for deer of the Michigan type of forest, white cedar is winter "meat and potatoes," while other browse is "salad."

NUTRITION, VITAMINS AND NOBEL PRIZE AWARDS

Two Nobel prizes, one in chemistry and one in physiology and medicine, were awarded this year for research closely related to nutrition and particularly for vitamin studies. Few of the Nobel awards have been made in this field.

The first time the Nobel prize committee recognized any of the scientific work on problems of human nutrition was in 1928, when Dr. Adolf Windaus, of Göttingen, Germany, received the chemistry award for his part in research showing that ultra-violet light, either in sunlight or artificially produced, will activate the chemical, ergosterol, and confer on it rickets-preventing or curative properties. The large number of substances now irradiated to make them potent sources of the antirachitic vitamin D resulted from such research.

Even more fundamental vitamin research won the 1929 award in medicine for Professor Christian Eijkman, University of Utrecht, Holland, and Sir Frederick Gowland Hopkins, University of Cambridge, England. Professor Eijkman was the first man to produce experimentally a disease of dietary origin. As a result of his work, lack of vitamin B was shown to be the cause of beri-beri, serious nerve disease. Professor Hopkins was first to show that animals, including man, can not live, grow and reproduce on a diet of fats, proteins and carbohydrates alone. The extra vital substances we now know as the vitamins.

This year the chemistry award was shared by Professor Paul Karrer, University of Zurich, Switzerland, and Professor W. N. Haworth, Birmingham University, England. The award in physiology and medicine went to Professor Albert von Szent-Györgyi, Francis Joseph University, Hungary. The first two investigated the complex chemical composition of vitamins A, B and C. Professor Karrer worked out the formulas for vitamins A and B_2. Professor Haworth and Professor Szent-Györgyi studied the anti-scorbutic vitamin C.

TWO NEW TREATMENTS AND TWO NEW DANGERS

Two new and spectacularly successful methods of treating disease have recently come upon the scene. With them, unfortunately, have also come two new dangers to health and life. The two new treatments are insulin shock for one widespread mental disease, and sulfanilamide for a growing number of infections or germ diseases. The danger is in the misuse or careless use of these new treatments.

The deaths of more than 80 persons who took a so-called elixir of sulfanilamide, which contained a poison besides the curative drug, has tragically emphasized the danger inherent in this and other new potent remedies. There is no guarantee that another similar tragedy will not occur. The elixir deaths occurred because the manufacturer and his chemist did not take the trouble to learn, either by consulting scientific literature or by making animal tests, the effect of diethylene glycol on the body. They simply found it would dissolve enough sulfanilamide so that two teaspoonfuls would contain a useful dose of the latter chemical.

Diethylene glycol, presumably, will not be used again in such a remedy. But physicians predict that manufacturers will market other sulfanilamide remedies which they will claim are better than the original sulfanilamide itself. These may or may not be dangerous, may or may not be better than sulfanilamide. Unless carefully tested on animals, their potential danger will remain unknown until the elixir tragedy is, perhaps, repeated.

The danger to life in insulin shock treatment can only be averted by constant watchfulness of the physician. "Constant" here means watching the patient every minute, literally, until he has recovered from the shock. This hazardous treatment can be given safely only in a hospital. Yet there have already been reports of its being given in the patient's home with near-tragic results.

THE PLAGUE OF MALNUTRITION

"When do we eat enough and properly?" That is one of the world's major questions to-day. There is no major famine plaguing mankind to-day, but the specter of hidden hunger is abroad in the world.

Millions of people in all countries are suffering from malnutrition. That means, not getting enough of the right kind of foot to eat. It means little children who are unnecessarily sick, boys and girls with bad teeth, people who lack energy to do more than merely exist.

The magnitude of the problem is emphasized by a report of a committee of the League of Nations that has had the aid of experts from many countries during the past two years. The surprising thing about this condition is that, as the League committee notes, it can exist in a world in which agricultural resources are so abundant and agriculture is so perfected that supply frequently outstrips effective demand. Quite evidently it is a problem for the statesman and international cooperation rather than merely a concern of the farmer, the food merchant and the housewife.

Improved nutrition means more use of what the dietitians call "protective" foodstuffs, such things as milk and vegetables. Because these are perishable they must be produced near where they are eaten. That means diversified local farm-

ing. But there are larger potential markets for the corn and wheat growers, too, because not every one has enough of these energy-producing foods. How to fight the hidden hunger plague: Tell the people about the right kinds of food to eat. Lower the cost of food. Let governments see to it that their populations are fed adequately, even though this means direct grants. The league committee is confident that in the long run such a program with a low relative cost would save incalculable suffering and economic loss.

SUBMARGINAL FARM AREAS CONTAIN "IMMOBILE" PEOPLE

Any plan for a wiser use of America's lands, retirement of submarginal regions, resettlement of the people, must take into consideration the human angles. Helpful in this connection is a study by the U. S. Department of Agriculture of a county in Kentucky, typical of the unprofitable farming region of the southern Appalachians. In Knott County, the ridges are narrow and the slopes are steep. Homes are small, one-story houses, unpainted or shabbily painted, with interior walls often covered with newspaper and worth an average of $343. Modern conveniences are lacking, food scarce. But many have flower gardens.

The average money income from a farm in Knott County is just $56 for each family each year. Knott County has poor roads, poor schools, limited sanitary and medical facilities. But the inhabitants of Knott County are what the experts of the U. S. Department of Agriculture call "immobile." They like Knott County. They have always lived in Knott County. In Knott County they hope to die.

Of the grown sons of the families interviewed, over 73 per cent. were still in Knott County. Less than 20 per cent. of the men and only six per cent. of the homemakers had ever been in all their lives beyond Kentucky or some adjoining state. Some of the men had been away to war. Some had gone looking for work. One girl had been on a honeymoon. Three had gone to funerals. Those who had lived away from Knott County had come back because they were homesick or because they "couldn't do no good" away from home.

In this modern day of loose home ties, wandering youth, drifting childless families, trailer residence and transient camps, population experts, psychologists and sociologists urge attention to this "immobility" of the Kentucky people before plans are made to move them from their submarginal acres.

BLOND COMMUNITIES IN NORTH GERMANY

Tallest blond communities in the world is the distinction claimed for three isolated villages in a marshland near Bremen. Nevertheless, they are not classified as pure Nordics by Dr. Christian von Krogh, of the Munich Anthropological Museum, who has just completed a special study of them. He calls them "Nordi-Falians"—by analogy perhaps with the tall, medium-blond, but rather round-headed Westphalians.

This group of people are landholding peasants, and they have held the same land for centuries. Two of the villages, Arsten and Habenhausen, have been in existence since prehistoric times; the third is comparatively new, having been founded in the eleventh century on land that had just been drained. Its name, Neuenland, englishes as "Newland."

The farmer families marry only among themselves, keeping the landless workingmen of the towns excluded from their family circles. A considerable degree of inbreeding has naturally resulted. Tracing family trees back four generations, Dr. von Krogh found only 69.4 per cent. as many ancestors as there would have been had no intermarrying occurred.

That inbreeding to this degree has not harmed the stock physically is evidenced by the condition of the people to-day. The average body height is five feet nine inches; it is the greatest group height known in Europe. The people have big

heads—high, long, and wide—with large faces to match.

Gentlemen of the community just about have to prefer blondes, unless they prefer to remain bachelors. Prevailing hair color is dusky blond, and over four fifths of the population have blue eyes.

NEW INDUSTRIAL JOBS FOR WOOD

Wood is just plain lumber, a building material, to most people, although they have heard that both the paper upon which newspapers are printed and rayon underthings are made from wood. Utilization of wood has many ramifications in modern industry to-day. But the editors of *Chemical and Metallurgical Engineering* in a survey discover that wood and its products will have many more uses in industry's to-morrow.

Take the troublesome liquids that result from the sulfite pulping process, first step toward newsprint and rayon. Sulfite waste liquor contains lignin, partner to cellulose in wood. Chemists are looking for jobs for lignin, confident that eventually it will be found to be as talented chemically and industrially as cellulose. In the state of Washington the sulfite liquor is used instead of oil for dressing the dirt roads, stabilizing the soil and giving a hard, dust-free crust. There is also research looking towards its use as fertilizer.

In Europe wood-working plants make gas from wood waste for power purposes and automobiles are fueled by wood-producer gas, made as you ride, with 25 pounds of wood the reported equivalent of a gallon of gasoline. Germany makes sugar and alcohol from wood by two different processes, but it is concluded that this would not be done profitably in the United States.

Then it is possible to squeeze ground sawdust and mill waste into hard dense products that are stronger than the wood that nature made. Inferior softwood lumber can be pressed into hard, dense attractive "hardwoods" and the lumber industry is looking into the commercial possibilities of this transformation.

Awake to the fact that they are not limited to the form of wood as produced by the tree, useful as that is, lumber companies are installing their own research staffs and scientists are now helping lumberjacks and millhands in one of the oldest of American industries.

DIESEL ENGINES

Few people have ever heard of the *Selandia* that twice yearly makes a round trip voyage of 22,000 miles to Bangkok in the distant Orient. For 25 years the *Selandia* has been plowing her way through the oceans and in 55 round trips has piled up mileage whose total distance is equivalent to three trips around the moon. The only noteworthy delay in all those years has been 10 days in port.

"Well, what about it," you ask. Only that the *Selandia* is the first Diesel powered motorship ever put into oceanic service and is the pioneer of the many newer vessels that have displaced steam in marine navigation. Ocean Diesel power is this year celebrating its silver jubilee.

That marine Diesel plants have traveled as far, figuratively, as the *Selandia* has in reality, is shown by the present total world's motor tonnage—11,900,000 gross tons. But even more important, Diesel power for a small motorship like the historic *Selandia* could now be fitted into a far smaller engine room, would weigh 30 per cent. less, yield 44 per cent. more power and drive the vessel at a speed 32 per cent. greater than does the *Selandia's* 1912 engines.

What another 25 years will bring forth in improvement is, of course, uncertain. But this much is certain. Diesel engines in ships have revitalized the development of marine transportation just as land transportation on the railroads is now undergoing a somewhat similar spurt for the same reason. The advantages of superiority swaying back and forth between competitors mark progress and make the wheels go round; peaceful revolutions, if you wish to call them that.

THE TRANSMUTATION OF HEAVY ELEMENTS[1]

By the late LORD RUTHERFORD OF NELSON

DURING the past few years our knowledge of the transmutation of the elements by artificial methods has grown with great rapidity, and practically all the known elements have been found capable of transmutation on a small scale when bombarded by fast particles of suitable type. By means of an ingenious apparatus called the cyclotron, Lawrence has been able to produce copious streams of protons and deuterons with energies as high as 6 million volts and moving with velocities even greater than the α-particles from radioactive substances. Such swift deuterons are capable of producing transformations even in heavy elements like platinum and bismuth. There is some evidence that the deuteron is broken up into its constituent proton and neutron in the intense field which exists close to a nucleus. The neutron may then be captured by the nucleus while the proton escapes. For example, four radioactive elements are produced from platinum, two of which have the same chemical properties as platinum, and are thus new unstable isotopes of that element, while the other two behave like isotopes of iridium. The interpretation of the results is complicated by the number of known isotopes of platinum, *viz.*, masses 192, 194, 195, 196 and 198. One of the radioactive isotopes of platinum breaks up with the emission of a negative electron and the other—an unusual event for heavy elements—breaks up with the emission of a positive electron. In the first case the isotope of mass 196 is believed to be involved; by the capture of a neutron a radioactive isotope of mass 197 is formed and this is transmuted by the emission of a negative electron into gold (mass 193). In the other case the isotope of platinum 192 forms a radioactive isotope 193, which by the emission of a positron forms a stable isotope of iridium (mass 193). One of the radioactive iridium isotopes is believed to be formed from platinum 196 by the capture of a deuteron and the emission of an α-particle. The radioactive isotope of iridium of mass 194 is then transformed into the platinum isotope 194 by the emission of a negative electron. The origin of the other iridium isotopes has not yet been settled.

The bombardment of bismuth by fast deuterons is of particular interest, as it leads to the production of a radioactive isotope of that element identical in radioactive and chemical properties with the natural radioactive body, radium E. This important result has been confirmed by showing that this artificially produced radium E gives rise to polonium—the first of the radioactive elements separated by Mme. Curie in 1897 from uranium minerals.

In general, the neutron is extraordinarily effective in producing transformations in the majority of the elements. In a number of cases very slow neutrons are far more efficient in this respect than fast ones. A suitable source of neutrons for such experiments can be obtained by bombarding beryllium with α-particles from radium. The fast neutrons can be slowed down by allowing them to pass through material containing hydrogen, for example, water or paraffin. In this way more than 80 new radioactive isotopes have been discovered, most of which break up with the emission of β-particles. The action of neutrons on the heaviest known element, uranium, has been the subject of close study by Hahn and Meitner during the past two

[1] Abstract of a lecture given before the Royal Institution of Great Britain, on March 19, 1937.

years. Work with this element presents special difficulties on account of its spontaneous radioactivity. Nine new and distinctive radioactive bodies have been observed when uranium is bombarded by slow or fast neutrons. All these break up with the emission of β-particles and with half-periods of decay varying from 8 seconds to 3 days. It may well be that other radioactive elements of still longer life will yet be observed. Hahn and Meitner have conclusively shown that not only are three new radioactive isotopes of uranium formed, but also radioactive elements of higher atomic number than uranium. By the application of suitable chemical methods it has been found that two of the radioactive bodies have the chemical properties to be expected for eka-rhenium atomic number 93, two for eka-osmium atomic number 94, and one for eka-iridium and for eka-platinum atomic numbers 95 and 96, respectively.

It has been found that the new radioelement formed from uranium breaks up in a series of successive stages analogous in many respects to the well-known sequence of changes which occur spontaneously in uranium and thorium. The results indicate that three new radioactive series are formed, two of which probably arise from the main isotope of uranium (mass 238) after the capture of a neutron, and the third may be due to a less abundant isotope of uranium (mass 235). The two main series of transformations are believed to be isomeric and to be the consequence of two distinct varieties of transformation of the same nucleus which is formed from uranium 238 by the capture of a neutron. The possibility of such an isomeric change had been suggested some time ago in order to account for the fact that uranium X appeared to give rise to two distinct β-ray products. All the new radioactive bodies formed from uranium break up with the emission of β-particles. The active uranium isotope of half-period 8 seconds formed by the capture of a neutron is transformed successively into eka-rhenium of period 2.2 minutes, eka-osmium period 59 minutes, eka-iridium period 3 days, and eka-platinum period 2.5 days. The latter presumably forms eka-gold, but no certain evidence of transformation has been observed beyond this stage. All these elements have nearly the same mass, 239, but, owing to the liberation of energy in the form of a β-particle, the mass of each successive element in the series must slightly decrease. With the exception of the uranium isotope of period 23 minutes, all these transmutations are produced both by fast and by slow neutrons. On the other hand, the 23-minute body can only be produced by slow neutrons of a definite energy and not by fast neutrons at all. This effect is a typical example of what is known as a resonance phenomena of which we have many instances in other elements. The effective neutrons are strongly absorbed by uranium, and Hahn and Meitner estimate their energy to correspond to 25 ± 10 electron volts. From the recent work of Dempster it is known that uranium consists of three isotopes of masses 238, 235, 234. The abundance of these three isotopes is of the order of 100, 0.3 and 0.07, respectively. It may be that the 23-minute body arises from the capture of a neutron by the isotope of mass 235. It does not appear that the bombardment of uranium by neutrons has any affect in accelerating the natural disintegration of this element. A complex series of transformations also arises when the second heaviest element, thorium, is bombarded by neutrons. Radioactive isotopes of radium, protoactinium and actinium are produced, but the exact nature of the transformations involved are still under investigation.

In the course of the lecture, the formation of α-ray tracks was illustrated by means of a specially constructed expansion chamber. By special arrangements

an image of the interior of the expansion chamber was thrown on a screen by means of the light from an arc lamp. At the moment of expansion the tracks of α-particles radiating from a source of polonium in the middle of the chamber were made clearly visible to the whole audience. The apparatus for this purpose was kindly prepared by Dr. E. Bretscher, of the Cavendish Laboratory. Experiments were also shown to illustrate the formation of radioactive bodies by exposure to slow neutrons, the elements indium and silver being used for this purpose. The marked β-ray activity produced in these elements and their rapid decay was shown by using a Geiger β-ray counter connected with a loud speaker. A preparation of uranium freed from uranium X was exposed to a source of neutrons, and the large increase of β-ray activity as a result of a few minutes' exposure was illustrated in the same way.

ELECTRON DIFFRACTION AND SURFACE STRUCTURE[1]

By Dr. G. I. FINCH

PROFESSOR OF APPLIED PHYSICAL CHEMISTRY, IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, LONDON

THE properties of waves are very different from those of bodies in motion. For example, though two waves can pile up together on meeting under favorable circumstances, they can also extinguish each other, and this is something which it is difficult to conceive of ever happening to two colloiding projectiles. Newton thought that light consisted of particles in swift motion, but when Fresnel and Young proved that light behaved like waves, Newton's corpuscular theory was abandoned. Soon after the war, however, it was found that light sometimes really did behave like a stream of particles and must therefore also be corpuscular in nature.

It seemed quite impossible to understand this duality in behavior until de Broglie, with a typically Gallic flash of genius, boldly postulated that all particles were guided in their motion through matter by attendant wave systems. When moving through empty space the particles in their behavior would show no signs of wave properties, but should do so when they came into contact with other particles. De Broglie calculated that the wave-length of the waves he believed to be associated with moving particles should be inversely proportional to their mass and speed, and would therefore be difficult to detect, except in the case of particles of exceedingly small mass, because otherwise the waves would be too short to be diffracted even by natural crystals, which are the finest gratings available. But electrons are more than 1,800 times lighter than the hydrogen atom, so that the length of the de Broglie waves associated with a stream of electrons moving at, say, 50,000 miles per second should be of the same order as in x-rays and therefore detectable by diffraction by crystalline matter.

The first experimental proof of the existence of de Broglie's moving-particle waves was carried out simultaneously and independently by Davisson and Germer with slow electrons and by G. P. Thomson with fast electrons. Thomson fired a stream of electrons through a crystalline film of gold. Knowing the structure of the gold and the speed and

[1] Abstract of a lecture given before the Royal Institution of Great Britain, on March 5, 1937.

mass of the electron, he was able to apply a quantitative test to de Broglie's law, which his experiments fully confirmed.

How are we to think of these waves which guide the electrons in their passage through the gold film? Experiments show that they only come into action when the electrons are moving through matter; in empty space there is nothing in the behavior of the electrons to betray their existence, and yet our experiments tell us that these waves are all pervading.

If you look at a fish swimming in water you will see that he is guided in the direction in which he moves by a wave motion which passes from his head towards his tail. When in the water the fish is, in a sense, like an electron passing through matter. Should the wriggling fish leap out into the air, he may then be likened to an electron speeding along through empty space, because the directions in which both fish and electrons move are then completely unaffected by their attendant wave motions. The fish model is, however, in reality inadequate; indeed, it does not seem to me to be possible to describe de Broglie's electron waves in terms of any concrete model. Rather must we think of them as something indefinite, like waves of emotion; where such waves are most intense, there will be the greatest chance of finding the associated bodies.

The discovery of the wave properties of moving electrons has provided us with a new and wonderfully powerful tool for the study of the structure of surfaces. Owing to their short wave-length and being electrically neutral, x-rays are very penetrating and can therefore tell us little or nothing about the structure of the surface of a body, although they reveal so much of what lies beneath. Electrons, on the other hand, carry a charge and are therefore so easily deflected by the strong localized positive charges of the atomic nuclei that they can not penetrate more than a few atoms deep below the surface. Thus the information afforded by diffracted electrons is virtually confined to the structure of the surface layers.

Of the several problems relating to surface structure which have recently been successfully attacked by the method of electron diffraction, one of the most interesting is that connected with the nature of polish. The late Sir George Beilby had shown, over twenty years ago, that polish does not simply consist in wearing the projections on a rough surface, but causes a sort of flowing of the surface material, almost as if it had been melted and then smeared like butter over the surface. Beilby concluded that the metal atoms in the final polish layer were all completely disarranged, just as they would be in a sudden frozen liquid. Many workers have since thought that Beilby was wrong, so Thomson, hoping to decide the issue, studied the diffraction of electrons by polished metal surfaces. Now a wave probe, whether it be x-rays or a beam of swiftly moving electrons, can only give information about a body when its structure exhibits some regularly repeated feature or features. Thus, in a crystal or crystal surface, the atoms are arranged in a perfectly orderly manner which is repeated many times when the crystal is not too small. In an amorphous substance, however, the atoms are jumbled up, so that practically the only regularly repeated feature is the size of the atoms, or, in other words, their nearest distance of approach to each other. In such a case, the diffraction pattern should consist only of a few very diffuse haloes; hence, when Thomson found that the electron diffraction pattern of polished metal surfaces consisted of broad fuzzy rings or haloes, similar to those obtained by x-rays from liquids like mercury or from amorphous substances like glass, he concluded that Beilby was right in supposing the polish layer to be amorphous. Somewhat later,

however, Kirchner found that under certain circumstances metal surfaces which were known to be crystalline could also give haloes, a discovery which left the issue still in doubt.

In the meantime, while working on an entirely different problem, Dr. Quarrell and I happened to observe that a thin film of zinc crystals when freshly deposited on a cool newly polished surface of copper gave good electron diffraction patterns characteristic of zinc crystals. The pattern, however, rapidly faded and finally disappeared, although if the copper surface had not been previously polished but was crystalline, no such fading was ever observed. The gradual weakening of the diffraction patterns meant that the zinc crystals were being destroyed and were in fact being dissolved by the polish layer of copper, which thus exhibited a property characteristic of a liquid and not shared by the corresponding crystalline surface.

How easy it must be for liquefaction of even highly refractory surfaces to occur when they are being polished has been admirably demonstrated by Dr. Bowden and Dr. Ridler. They took advantage of the thermo-electric current which flows when two different metals are joined together into a closed circuit, and one junction is hotter than the other. It is easy to measure this current and thus determine the difference in temperature between the two junctions. In this way Bowden and Ridler showed that the temperature of formation of the polish, or as it is now known the Beilby layer, on a metal surface is equal to the melting point of the metal itself.

The study of polish has important bearings upon the problem of wear in engines. The essence of the process of "running-in" an engine is a sort of vigorous polishing action, by which a deep Beilby layer of amorphous material is formed on the working surfaces. The reasons why we want to build up such a polish layer before subjecting the bearing surfaces to heavy loads are two-fold. Firstly, the Beilby layer is harder and tougher than the corresponding crystalline surface. Also, unlike polished surfaces, freshly machined surfaces are not really smooth, but have many sharp little crystalline peaks projecting above the mean level of the surface. Thus the load is not uniformly distributed over new bearing surfaces, but concentrated on to a few almost point-like areas, so that the oil film meant to prevent metal-to-metal contact is easily broken down, with the result that the high temperatures generated when the metallic surfaces rub directly against each other sometimes cause them to fuse and weld together, leading to seizure or bad scoring and excessive wear.

Although the polish layer is formed by a process of fusion and smearing of the flowed substance over the surface, the freshly formed Beilby layer on some surfaces immediately recrystallizes on cessation of the polishing action. This occurs in the case of sapphire. The oxide film normally formed on an aluminium surface is amorphous, but the action of polishing causes it to crystallize into sapphire. This explains why the aluminum piston is liable to cause excessive wear of the engine cylinder. Unlike sapphire, however, spinel, a solid solution of aluminium oxide in magnesium aluminate, on polishing forms a permanently amorphous Beilby layer, which does not recrystallize like the sapphire and so produce sharp projecting crystal corners capable of cutting through the oil film to score the metal cylinder. Thus a thin coating of aluminium-magnesium alloy on an aluminium piston should lead to reduced wear, because the mixed magnesium and aluminium oxides film on its surface is "spinelized" by polishing, and the resulting spinel film remains amorphous and smooth.

THE NEW YORK STATE MUSEUM[1]

By Dr. C. STUART GAGER
DIRECTOR OF THE BROOKLYN BOTANIC GARDEN

ONE hundred years is a good old age in the life of an individual. Few persons live to attain it. But what is one hundred years in the life of an institution? Harvard College, the oldest school of higher education in America, was two hundred years old, and the University of Paris about seven hundred years old, when this museum began to take shape in the imagination and aspiration of its founders.

The word "museum," in its modern sense, was first applied to the Ashmolean Museum at Oxford. This takes its origin from "Tradescant's Ark" or *Musaeum Tradescantianum,* an assortment of miscellaneous "Rarities" collected by John Tradescant, Sr., beginning in 1625, or earlier. Tradescant's collection, combined with that of Elias Ashmole (1677) was presented to Oxford University and has since been known as the "Ashmolean Museum." This was about 260 years before the New York State Museum was organized.

The Bologna Museum, initiated by the natural history collections of the botanist-naturalist Aldrovandi, about 1600, is approximately 330 years old; the British Museum (1753), 184 years old; the Museum d'Histoire Naturelle, Paris (1793), 144 years old; and the Charleston Museum (1773), in South Carolina, the oldest in the United States, 164 years old. Among "modern" museums, therefore, this one has hardly reached adolescence.

The shortness of the span of one hundred years is emphasized by the fact that the present speaker has known personally every one of the four directors of this museum. How well I recall the afternoon in the winter of 1896 when, as a graduate student in the State Normal College (now the New York State College for Teachers), I had the temerity to call on that great scientist, Dr. James Hall, first state geologist, first state paleontologist, first director of this museum, beginning when it was called the State Cabinet of Natural History. If I had been another noted scientist, I could not have been received with more courtesy and consideration. Even then, I sensed the great opportunity I was enjoying as Dr. Hall, 86 years of age, opened drawer after drawer of his precious specimens, made classic by his study of them. He poured out more wisdom than I was able to absorb, but the inspiration he gave remains to this hour. Moreover, he nearly performed a miracle, for he almost converted an embryo botanist into a geologist.

Strictly speaking, I can not claim acquaintance with Dr. Hall's successor, Dr. Frederick J. H. Merrill, for our meeting was confined to a brief introduction; but Merrill's successor, Dr. John M. Clarke, I knew well. I remember clearly his telling me of his appointment as director of science and of the State Museum in 1904, before it had been publicly announced.

Dr. Clarke was not only an accomplished investigator and administrator; he was a man of broad culture and master of a literary style that has not yet become too common among scientific men. Earl Grey, of Fallodon, writing in his Autobiography of Jowett, the famous master of Baliol College, noted that while Jowett was not a great talker, "what he did say was like the result of distilled thought with a sort of finality about

[1] Address (for botanical science) delivered at the seventy-third convocation of the University of the State of New York, celebrating the one hundredth anniversary of the establishment of the Division of Science and State Museum. Albany, October 15, 1937.

it. . . . It was as if he made thought visual."

Such was the *quality* of the *language* of Dr. Clarke in his scientific papers and monographs, which carried on the tradition of high excellence for the scientific output of this museum.

The fourth and present director of the museum, Dr. Adams, is one of the founders, in America, of the new science of ecology (the study of organisms in relation to their environment), and is recognized in scientific circles as one of its leaders. It has been my pleasure to have known him for nearly twenty years, and to have been associated with him in establishing and conducting the journal *Ecology*.

So far as I know, he has never fallen from rectitude but once. In a moment of weakness he recently wrote to me, "My first interest in natural history was in plants." But the insidious influences of the animal world finally undermined his botanical uprightness and now everybody has found him out, unashamed as a zoological ecologist.

From this brief history you will see that I have a personal interest in this centennial celebration far greater and deeper than could have been imagined by those who incurred the risk of assigning me a place on the program.

Now in such museums as those of Tradescant and Ashmole, which I have mentioned, the objects were "often badly placed, and were nearly always arranged in relation to their accidental and not their distinguishing features. Things were disposed according to size, like pipes in an organ, and the two sides of a room had to balance so that the most incongruous objects were often placed alongside of each other."[2] As Murray has pointed out, this was in part a reflection of the poorly organized state of scientific and educational ideas of the time. But the conception of a museum as a "cabinet of oddities," of the curious, the unusual, the *amazing or amusing, rather than of the* significant and instructive, has had great persistence.

But what is a museum?[3] Dr. Clarke, in his address at the "public opening" of this building, referred to the original connotation of the word as a *temple of the muses*, which he aptly paraphrased as "the shrine of intellectual aspirations." He proceeded to point out how closely the conception of the New York State Museum, as formulated by the regents of the university, approximates the Greek idea.

The museum, as the Greeks understood it, was of primary importance in their intellectual life. The most famous pupil of Aristotle, the botanist, Theophrastus, who died in the year 287 B.C., said in his last will and testament: "First of all, I wish everything about the Museum and the statues of the goddesses to be made perfect and to be adorned in a still more beautiful manner than at present, wherein there is room for improvement." The museum, which he had built for a school, was his first concern, and of equal importance with his religion. Everything about it was to be improved.

The most famous museum of antiquity —that established during the Greek-Egyptian period at Alexandria by Ptolemy I, about 320 B.C.—was, as is well known, a great state institution, comparable to our universities—the intellectual center of its contemporary world, with as many as 14,000 students at the height of its activity. During the past fifty years museums have been steadliy developing in that direction, maintaining as their distinctive feature a collection of objects placed on public exhibition.

But in all the ancient world there was nowhere an institution that corresponds

[2] Murray, "Museums: Their History and Use," p. 206. Glasgow, 1904.

[3] Throughout this article the term "museum" is used to designate a natural science museum, as distinguished from those of art, history, commerce, etc.

to what we now understand by the word museum. The modern museum may be most adequately described in terms of its activities:

(1) *Research* (including exploration) for the purpose of extending and perfecting our knowledge.

(2) *Publication of the results of research,* in both technical and popular form.

(3) *Permanent preservation* of the objects which have been the subjects of research, together with pertinent data.

(4) *Public exhibition* of some of these objects for the purpose of public education.

(5) *Conducting an educational program* of lectures, docentry and courses of instruction, with special community service, such as maintaining a bureau of free public information, trade services, etc.

Such a full picture as this of the modern museum needs continual restatement and emphasis, for the vast majority of those who go through the exhibition halls "to see the museum" have no conception whatever of what goes on behind the scenes. I sometimes wonder how many of those have who are depended upon to provide the necessary funds by legislative act or private benefactions, for some of the fundamental aspects of a museum are least amenable to exhibition.

The supreme importance of preserving the objects of scientific study can hardly be over-emphasized. "The images of men's minds remain in books," said Sir Francis Bacon. How important it is to preserve the images of men's minds is emphasized every time we think of the burning of the great library at Alexandria in 391 A.D. The learned world has never ceased to feel its impoverishment by the destruction of those documents. A similar loss is felt and a similar lesson is driven home by the burning of a portion of the New York State Library and many of its unique archeological specimens relating to the New York State aborigines in 1911.

But the objects preserved in a natural history museum are, for natural science, more fundamental objects than books. We can inherit scientific ideas (preserved in books and libraries), but we can not inherit the experiences that gave rise to those ideas and which give them validity. Each generation must realize them for itself. It behooves us, therefore, to do all we can to facilitate the entering-in to those experiences.

By preserving and exhibiting the objects of study which gave rise to the body of scientific ideas and literature, the museum helps make it possible, for every one who wishes, to repeat the experiences of the makers of science. This enables one to check up on the accuracy of the observations and the basis of the conclusions of others by studying the precise objects they studied.

How impossible it would have been for stories of "barnacle geese," the "Scythian lamb," monkfish, dragons and basilisks, and other fantastic tales of early explorers to have been handed on *and believed* if those explorers had been required, as now, to bring the objects they wrote about home for installation in the local museum!

But to think of a museum as merely a collection of objects on public exhibit is as far from reality as to think of a church as an edifice, or of a university as a collection of buildings. The essential thing about a museum is the scientific and educational activities of its staff. The exhibits are a means to a double end which is the advancement and dissemination of knowledge. The two aims are of equal importance.

This museum had its origin in a program of scientific research; it has been and must always be nurtured by the researches of its staff. The museum of a great state can not be merely a popularizer—a purveyor of second-hand information. The proper installation of the exhibits and their revision from time to time to keep them abreast of ever-

advancing science makes it essential that the museum staff shall include the research type of men, and that they shall be required and encouraged in the tradition of this museum for productive scholarship.

Nor is a museum, as here conceived, confined to its exhibition halls or the building it occupies. It has been said of a great state university that its campus is the state. In the same sense, this museum permeates and should permeate the entire state of New York. Its program of research is to study the natural resources of the state and to publish the results. Its scientific and educational activities always have been and always should be state-wide.

Dr. Adams has asked if I would not speak specially of the botanical work of this museum and of the value of botany from the cultural as well as the practical point of view.

There is not time, in this address, to attempt a full résumé of the botanical publications of the State Regents, beginning in 1831; and others, fifty years from now, will appraise and praise the important scientific work of the present botanical personnel. But in any historical account of this institution, however brief, it will always be essential to mention the work of two botanists—Dr. John Torrey and Dr. Charles Horton Peck, whose contributions during its first 75 years laid indispensable foundations, and made both them and this museum favorably known throughout the scientific world.

I will tell you a true story that is stranger than fiction. In 1818 there was a botanist, named Amos Eaton, who had acquired a wide reputation as a "popular" lecturer on botany and other natural history subjects. So great was his fame that Governor Clinton, in that year, invited him to deliver a course of lectures before the New York State Legislature. It actually happened! And, more than that, this course of lectures was one of the chief causes leading to the establishment of the State Geological Survey.

My story grows stranger and more interesting. Did you ever hear of an inmate of a state prison becoming the chief source of inspiration to a great scientist? In 1810 one William Torrey was appointed fiscal agent to the state prison at Greenwich, now Greenwich Village, a section of lower New York City. William's young son, John Torrey, attracted the attention of one of the inmates, who had been imprisoned for debt. If he had lived in these days he would have been "reorganized"! That inmate was the same Amos Eaton, who later, by his eloquence, helped inspire the legislature to take the first step that led to the establishment of this museum. It was from Eaton that John Torrey got his first inspiration for a scientific career.

Now in studying the botany of a new region, such as New York State once was, the first requisite is to know what the plants are that compose the regional flora, and the early publications of the museum were "catalogues" of the plants growing spontaneously in various parts of the state. It is of interest to note that the second of them, published in 1833, was by a pupil of Torrey, a young man named Asa Gray, who, in time, became the best known and, according to some, the greatest American botanist.

In 1839 Torrey, who had been made a fellow of the Linnean Society (London) in recognition of his high attainments, was appointed "botanst" and commissioned to write a "Flora of New York State." This work, now a botanical classic, was published in 1843 in two volumes of more than 1,000 pages, describing nearly 1,500 species, "with remarks on their economic and medicinal properties."

It was a fortunate thing that the state was able to find a man like Torrey, able and willing to perform this service. The work had to be done, sooner or later, and, if Torrey had not done it, it would prob-

ably, in those days, have been undertaken by some European botanist in a manner less advantageous to American science. Botany had not, at that time, won general recognition as a regular subject of university instruction, and all the while that Torrey was engaged in his encyclopedic botanical research he was, for 28 years (1827–1855), professor of chemistry and mineralogy in Columbia University, and simultaneously, for nearly 25 of those years (1830–1854), professor of the same subjects in what is now Princeton University.

The second great staff botanist, Dr. Peck, I knew and corresponded with. His first paper published by the regents was a "List of Mosses of the State of New York," which appeared in 1866. In the same year, as a young man of 33, he was appointed to carry on botanical investigations for the state and to look after the botanical collections of the State Cabinet. In 1870 the State Cabinet, by act of the Legislature, became "The Museum of Scientific and Practical Geology, and General Natural History."

Dr. Peck's "Report of Botanist" for 1867, not published until 1870, was the first of the long series of 46 annual reports, covering the years 1867–1912 inclusive, and known throughout the scientific world as "Peck's Reports." Each was an important contribution to our knowledge of New York State fungi and to the general subject of mycology. In the meantime, he was also publishing other papers on both fungi and flowering plants, determining specimens for other people all over the country, doing field work, caring for the herbarium, attending to a heavy correspondence without a stenographer, and handling a certain amount of administration.

Dr. Peck began his botanical studies by himself while a student in the old State Normal School, here in Albany, before botany was included in the curriculum. He became state botanist in 1883, and his resignation, necessitated by the infirmities of years, took effect in January, 1915. While in office he described about 2,500 species of fungi *new to science,* the majority of them from specimens collected by himself. For much of his career he had quite inadequate support and a salary that was meager, out of all proportion to the value of his services. He was for many years the despair, the inspiration and a great help to younger students of plant life. His writings will always have to be consulted by any one who undertakes further work on the fungi; they are not exceeded in importance by those of any other American student, and by perhaps only one (Saccardo) in the whole world.

What a remarkable record of scientific activity for one man, beginning before the age of 33 and continuing until he was nearly 80 years of age. During that period many botanists took their introductory college course in botany, attained a reputation, and passed on. For his long life as well as his scientific output, he was a landmark in the botanical world and one of the glories of this museum. In harmony with the museum ideal, the objects of his study were carefully preserved and have contributed to make the New York State Herbarium one of the most important in existence and one of the priceless treasures of the Empire State. In 1916 a collection of mushroom models in wax, by Henri Marchand, was presented to the museum as a memorial to Dr. Peck.

It should never be lost sight of that the credit for the superb work of this museum is due in largest measure to the members of its scientific staff. The work of these men was little understood and of only slight interest to the appropriating powers, who were little concerned as to whether the quarters were adequate; and the compensation was based, not on the value to the state of the services rendered, but on the principle of paying only as much as was absolutely necessary. That the state was able to obtain and hold

the services of these men was due solely to their devotion to science and its high ideals.

It is fitting, on this occasion, to recall that practically all the great museums of the modern world owe their origin and much of their most valuable exhibits to the collections and benefactions of private individuals, including scientists, princes and kings, and only subsequently, if at all, became the property of government.

With reference to the "pure science" work of this museum (in botany and other sciences), the question has, no doubt, already occurred to some one in this audience, "What is the good of knowing all that? Why should a great state spend any money for the study of its wild flowers, or especially of its toadstools and mushrooms?" That question has always been asked and always will be asked, and it will forever be a responsibility of science to try to answer it. Those who ask it are apt to be most readily satisfied by an answer that shows some economic gain resulting from the new knowledge.

There is not time here to point out in detail the advantage to practical agriculture of studies of plant breeding, plant diseases and botanical soil-organisms. According to the statistics of the United States Department of Agriculture, the savings from loss and the gains in production are measured in hundreds of millions of dollars per year.

And if, like Joshua, I could command the sun to stand still, we could summarize the very interesting story of how botanical science has served human needs in helping to solve the problems of soil erosion in the "dust bowl" and elsewhere, of the purification of water supply to our cities, the preservation of seabeaches, the diseases of fruit, vegetables and food fishes, the breeding of new and improved fruits and vegetables and flowers, and in other ways, not forgetting the improvement of our minds and the enrichment of life.

Mr. Joseph Chamberlain in 1898, when secretary for the Colonies, speaking in the House of Commons, said: "I do not think it is too much to say that at the present time there are several of our important Colonies which owe whatever prosperity they possess to the knowledge and experience of, and the assistance given by, the authorities of Kew Gardens [the Royal Botanic Gardens at Kew]." And the director of the National Botanic Gardens at Kirstenbosch, South Africa, who quoted Mr. Chamberlain, added, " . . . what Kew has done, other Botanic Gardens all over the world have done."

And let it be stated here with emphasis, and without qualification, that there has never existed, and does not now exist, a great industry or a commercial activity that does not owe its existence or its continuing prosperity to the fact that some one, some time, endeavored to find out something for the sheer pleasure or satisfaction of knowing it. The electrical industry, with all its myriad ramifications, and agriculture in its entirety, are colossal illustrations of this truth.

Science advances both "by leaps and bounds," and by the steady plodding of trail blazers along uncharted pathways. The "leaps and bounds" are few and far between. They are the contributions of the great intellects that appear only at intervals, and first catch the vision toward which the blazed trail has been leading—the Aristotles, Galileos, Newtons, Linnaeuses, Lyells, Agassizes, Halls, Darwins, Pasteurs and Mendels. They give from time to time the necessary new impetus to the great army of trail followers (investigators), who plod along, many without a particle of genius, collecting facts for the inspired fertilizing synthesizer, whose formulation of some great new conception rejuvenates the work of science as truly as the sperm

rejuvenates the egg-cell in fertilization, initiating a new embryo-idea which fairly stretches the human mind and provides the program of scientific research for another generation or so. Among these conceptions in botanical science are the following:

(1) *The existence and nature of cells,* and the fact that plants and animals are aggregates of cells. This not only placed the science of biology on a new and more rational basis, but became the foundation of the new science of "cellular" pathology and physiology, of such tremendous importance to medical theory and practice. It ultimately made possible the scientific study of heredity. This great generalization was first formulated in a botanical laboratory by the botanist, Schleiden.

(2) *The elaboration of the Darwinian theory to explain the fact of organic evolution.* As is well known, this revolutionized the entire range of human thought, and was based in part on a study of plants by Charles Darwin and others.

(3) *The "Mutation Theory"* of variation and heredity, one of the most invigorating contributions to biological philosophy since Darwin, stimulating thought and initiating a vast amount of illuminating research, was formulated by the botanist, Hugo de Vries, primarily by studies of the evening-primrose.

(4) *The Mendelian theory of heredity.* People have discussed the subject of heredity from Biblical times to the present, but the consideration was first lifted from the futile realm of forensic debate and placed on the sound basis of experimental science by the study of the garden pea by the botanist, Gregor Mendel.

These are only outstanding examples of the great illuminating ideas whose cultural value in emancipating the human mind from bondage and bigotry and superstition is among the most precious possessions of mankind. They are primarily the result of the study of plants without reference to economic ends; they are some of the mental "leaps and bounds" taken by the geniuses of science.

But there is another important consideration, seldom referred to, in discussing the value of accurately observing, describing and classifying natural objects —such, for example, as Torrey, Gray, Peck and others have done for the flora of New York State. This work supplies the atoms and molecules which are indispensable for building up the great mass of botanical knowledge, which is essentially not a mere accumulation of facts, but a body of concepts—of laws and principles. It is such work as theirs that makes it possible for us to think at all, and to exchange thought.

We can not think in terms of individual notions, such as "this good man," "that beautiful person," "my rose," "your orchid," but only in terms of general notions—goodness, beauty, roses, orchids. But, as is well known, general notions or concepts are all derived from individual notions or percepts by processes of comparison and abstraction; hence the vital importance of having the underlying facts accurately observed and classified on a rational basis; otherwise, our concepts are incomplete, inaccurate and misleading, and our thinking is futile.

If our concept of "rose" includes only the flowers we buy under that name from the florist it is incomplete, for the studies of the botanist reveal to us the fact that apples and strawberries, and sweet peas and wisteria belong in the same group or natural order as the roses of the florist and the wild rose.

If, as Theophrastus did, we place all trees in the same class because of their tree-like habit of growth, our concept is inaccurate, for the careful observations and comparisons of the botanist show us that some trees are related to the violets, some to the potato, some to the buttercups, and so forth. Such conceptions come as a genuine revelation to the layman in science, just as they did originally

to the botanist. In fact, such truths were missed completely in the early history of botanical science through the untrained and inaccurate observations of the pioneer students of plants who supplied the data—the atoms and molecules of thought, on which the early syntheses (the classical and medieval body of botanical science) were based.

If it is of any importance for us to have an accurate and comprehensive knowledge of plant life, of nature as a whole, then we must recognize how indispensable it is to have the foundations securely laid by the painstaking work of those who provide the essential underlying data; who can and will devote their time to accurate, thorough and unprejudiced observation and description. They supply the knowledge which is the basis of understanding, which is the essence of science. For example:

The work of Torrey and others has given us information as to what plants grow spontaneously within the borders of New York State. By comparative studies we learn the surprising fact that the flora on the summit of the state's highest mountain (Mt. Marcy) is more closely related to that of sub-arctic regions than to the plants at the base of the mountain. If we rest here we have knowledge but no understanding.

Such work as Torrey's and Peck's and Asa Gray's has given us knowledge of the flora of the east coast of Asia and the east and west coasts of North America. By comparisons we learn, contrary to our expectations, that the flora of eastern Asia is not as closely related to that of western North America as it is to that of the more remote Atlantic seaboard. Here again we had knowledge but no understanding, until the great thinkers of botany, pondering the mass of facts accumulated by the Torreys and Pecks, were able to explain these biological puzzles by reference to events that took place with the advance and retreat of the continental ice sheet during the Glacial Period.

Then we understood. It all seems so simple now; but only one man, Asa Gray, was able to solve the latter problem. And to come to an understanding of problems of such reach and difficulty is to take another tiny step toward the goal we would all like to reach, but never shall—the understanding of the universe, and of ourselves, and the meaning of it all. It is such accomplishments as this that enlarge the mind, and enrich the spirit, and make life worth living.

In the light of such considerations, work like that of Torrey and Peck—the laborious, but necessary, observing, describing and classifying—takes on a wholly new significance.

If a great state is fortunate enough to find some one able and eager to devote his life to studying the fungi of the state, as Dr. Peck did, it should by all means encourage him and subsidize him. If no one had ever studied fungi, we should have had no yeast, which is a fungus. It would exist, of course, just as the bacteria did before Pasteur, but not for us. Whole industries based upon the process of fermentation would never have existed.

But the point I wish to stress is this: Parallel with education, there is nothing more important for the welfare of a people than the advancement of knowledge—nothing more important for a great state to do than to promote this activity, to organize it and to finance it commensurately with its importance. It is correlative with the promotion of law and order, and morals and religion.

Hall and Torrey and Peck and their associates knew that they could render this state and the whole world an invaluable service beyond the mere discovery of mineral and vegetable wealth. That service was the advancement of positive knowledge.

The first director of this museum might

have restricted his energies to the endeavor to locate coal, oil and minerals in the rocks of the state. Quite possibly that was the official expectation. But he also became the "founder of stratigraphic geology and applied paleontology in America" (W. J. McGee), and "laid the grounds for a rational theory of mountains, which must be regarded as one of the most important contributions to geological science" (Hunt).

A museum is an organic thing. Its germ is an idea. Its essential characteristics are activity and growth. It depends upon nourishment. It remains useful only so long as it continues to perform vital functions. Whenever it becomes merely a static exhibition of labeled objects it has become, not a museum, but a mausoleum.

Like the so-called coral reefs, what it does to-day should become the foundation of what it will do to-morrow. Those who have labored through the first brief hundred years of its life have only laid foundations; but like the foundations of a building, they largely determine the form and proportions of the superstructure. And how can a builder proceed with a superstructure unless he gives careful attention to the foundation?

This is the purpose of anniversaries—not primarily to exult over the past, however glorious it may be, but to make sure that the work of to-morrow shall rest securely on the foundations that have been laid, and by a brief survey of the accomplishments, and especially the personalities of the past, to gather new inspiration and vision for the work that must go on, and on, and on—so long as anything remains unknown and mankind retains its God-given desire to know. These are the eternal prerequisites of science and education.

Let us not be impressed with the idea that the New York State Museum is 100 years *old;* it is 100 years *young.* It has all the characteristics of youth—it is still outgrowing its garments of yesterday; it is still learning; it has the vigor and aspirations and curiosity of youth; it has the urge and the will to achieve; its career is mostly ahead of it; it is forward-looking.

May the promise of its youth and the need of its services, as well as the invaluable accomplishments of its past, impress the powers that be to provide the necessary funds, not only for the more nearly adequate building which it merits, but to continue its record of a scientific and educational staff of the most able men to be had, who will effectively carry on the glorious tradition of personalities and accomplishments which have commanded the admiration and respect of the learned world for the past hundred years. No money could be appropriated by the legislature of any state that could have fuller justification or yield larger returns on the investment.

I could not close more fittingly than with a quotation from Dr. Clarke's address, delivered twenty-one years ago at the "public opening" of this museum: "All that has been achieved," he said, "in the making of the State Museum is overshadowed by the hopes of its greater service to the public."

SCIENCE AND DEMOCRACY[1]

By J. McKEEN CATTELL

Haply the swords I know may there indeed be turned to reaping tools,
Haply the lifeless cross I know, Europe's dead cross, may bud and blossom there.

THUS, as told by our poet, spoke Columbus in his prayer, taking his way along the island's edge. From that day, October the twelfth, 1492, we may date, in so far as a continuous process of evolution may be assigned a beginning, both modern science and modern democracy. The circle of the earth was closed by a scientific discovery following patient induction, bold theory and persistent labor; at the same time a new world was opened for the democracy in which we live.

Without science there could be no democracy. It is the application of science to agriculture, commerce and the arts that has made democracy possible. So long as food, clothing and dwellings were produced and transportation was carried forward by unaided manual toil, so long as plague and famine, disease and premature death were unchecked, it was impossible to give equal opportunity to all. Plato had to provide slaves for his republic; serfs and peasants have been partly emancipated only in our own time. It is the applied science of the past hundred years that has made child labor needless and universal education possible, that has made the still existing semi-slavery of industry wanton and intolerable.

Science there had been and a kind of democracy, notably in the marvelous efflorescence of the Greek period, the radiation of whose light has never since been wholly quenched. The glimmering of the so-called dark ages was dawn rather than twilight. The vigorous tribes of the north partly submerged and partly assimilated the culture of the Mediterranean. Sacerdotium, Imperium, Studium—the church, the empire and the universities—these institutions both resisted and spread the spirit which on the one side gave birth to trade guilds, trial by jury and constitutional governments, and on the other to art, literature and science; for personal liberty and intellectual performance have advanced together.

Salerno, the earliest of universities, was a school of medicine, and for centuries maintained its prestige as such, coordinate with Bologna as a school of law and with Paris as a school of theology. At Salerno in the eleventh century women were among the teachers and Jews were not debarred. The university probably developed from the municipal schools of the Roman Empire, and this also holds to a certain extent for Bologna. When at the beginning of the twelfth century, Irnerius lectured at Bologna on civil law, the Italian cities were attaining their independence, resisting the emperor on the one side and the pope on the other, subduing the feudal lords of the surrounding country and the bishops within their walls.

With the rising tide of democracy came commerce and the industrial arts; population and wealth increased incredibly amid incessant wars. The civic life of those republican cities of northern

[1] Convocation address given at Indiana University in 1912, now printed without alteration after the lapse of twenty-five years. It has a certain historical interest (at least to the writer) for it appears to be the first statement of the dependence of modern civilization on the applications of science. An excuse for the rhetoric may be found in the circumstance that the address was prepared for a general audience.

Italy paralleled that which had flourished fifteen hundred years before in the Greek democracies. From it came the renaissance of letters, art and science, the foundation of universities. In 1265 was born Dante, second "among the sons of light," master of the science of his day, prior by election of republican Florence. Imagine this town of Bloomington, about the size of Florence, having a Dante to elect as mayor, a Giotto to paint his portrait—and think of those two hundred years of Florentine history, genius so diverse as shown by Boccaccio, Macchiavelli and Savonarola; the great performances in architecture, sculpture and painting, culminating in Leonardo and Michelangelo.

Migrations from Bologna in the twelfth and thirteenth centuries established universities in a number of Italian cities, that of Padua becoming the most famous. While the Roman civilization to a certain extent survived in Italy, such scholarship as existed north of the Alps was carried there by the church. The old imperial and municipal schools were swept away by the barbarian invasions; but schools were established in the monasteries and cathedrals. Abelard lectured on theology and philosophy at Paris in the cathedral school of Notre Dame at the same time that Irnerius lectured at Bologna on civil law.

Thence followed the University of Paris with its dominant interest in the scholastic philosophy. Unreal as most of the dialectic appears to us, it was a true advance in scientific method to argue as Roscellinus and Abelard did that faith depends on reason. Paris was becoming a political, industrial and commercial center; guilds were established; there were struggles for municipal liberties and constitutional guarantees. The Counts of Paris became the Kings of France. The crusades on the one hand, the universities on the other, brought men together from all the nations of Europe. Paris became their intellectual goal.

The conditions leading to the development of Oxford as one of the three most notable medieval universities are somewhat obscure. The place was convenient of access and chance appears to have drawn to it a migration of English scholars from Paris in 1167. But Oxford became great because Great Britain then as always produced great men. In those days the university led in science and mathematics. Grossetête lectured on optics and wrote on agriculture; his pupil, Roger Bacon, was the prophet of the inductive sciences.

Bacon was perhaps born in 1215; in that year King John was forced by the barons to sign the magna charta. This instrument which reaffirmed the Saxon laws is regarded as the foundation of English liberty and constitutional government. The king was made subject to law, and the barons granted to their vassals the privileges they obtained from the king. No freeman was to be imprisoned or fined except by judgment of his peers or by the law of the land. The only mention of the villains or serf-peasants is that their implements could not be taken away by fine. The barons and the kings were not concerned with democracy, but their centuries of quarrels led that way.

Political and social democracy had to await the slow development of science; only the nineteenth century supplied the applications of science to industry, agriculture and commerce, to the limitation of disease and premature death, which make it possible for the twentieth century to develop a true democracy. None the less it is the case that the parliament which had its beginnings at the time Roger Bacon was born has developed with the growth of science until to-day, when Great Britain has the most democratic government hitherto attained by

a great nation. England has had the most continuous leadership both in scientific productivity and in parliamentary and democratic government.

From the time of Roger Bacon to the time of Columbus and Copernicus, universities were founded throughout Europe. If the University of Padua had not been established, and if Columbus had not studied there as a boy, he might have been an adventurous sailor, but he would not have discovered the West Indies. If the University of Cracow had not been established and if Copernicus had not found there and at Bologna and Padua teachers of mathematics and astronomy, he might have been a canon at Frauenburg, but he would not have written on the rotation of the celestial bodies. If the University of Wittenberg had not been established in 1502 and Luther had not five years later become a professor there, he might have remained a monk in the Erfurt convent; he would not have led a procession of professors and students from the gates of the university to the market place to burn there "the execrable bull of antichrist."

Luther had the support of the university in which he taught, but his books were burned at the University of Paris. It is the thesis of these remarks that universities and scientific men have been the causes of political and social democracy, and consequently that their support and encouragement should be one of the principal concerns of a democratic government and of a democratic people. But the ways of providence are indirect. While the ultimate effects of universities and of those engaged in scientific research and invention have been to make democracy possible and necessary, their immediate influence has usually been on the side of conservatism, in support of the king, the aristocracy and the church. Universities have been dependent on church and state and on wealthy patrons; scientific men have come in the main from the kleptocratic classes or have been absorbed into these classes. Those only can obtain the prolonged training required who come from families having money or who depend on some charity for their education. Scientific research and invention are not paid for by the people whom they benefit; the rewards have been patronage and social recognition.

Copernicus was a canon of the church; he dedicated the "*De revolutionibus de orbium coelestium*" to the pope and delayed its publication until the end of his life to escape possible censure. Columbus was strict in his piety; one of the main objects of his voyage was to convert the Grand Khan to Christianity. He sought through the courts of Europe for a patron. Kepler was court astrologer. Galileo received pensions from the Medici and from the pope; he denied his own science. Descartes suppressed his book on hearing of Galileo's troubles; his favorite disciples were Princess Elizabeth and later Queen Christina, in attendance at whose court he died. Harvey was physician to King Charles and attended him in the battles of the civil war. Cassini and Huygens went to Paris under the patronage of the king of France. Hobbes was tutor to the nobility and to the king, whose divine rights he championed. Newton gave up his professorship at Cambridge to accept a lucrative position in the mint; he wrote on the scriptures and was a welcome visitor at court. And thus the list of lesser founders of science might be rehearsed—they came from the upper classes, or from the middle classes that were at the same time exploiting and subservient. They had little wish to promote radicalism and democracy, but they did so far more effectively than any agitators or any legislators who have ever lived.

De Candolle found that of 100 foreign associates of the Paris Academy of Sciences, 41 came from noble and wealthy families, 52 from the middle class and

seven from the working class. Galton found that of 96 contemporary leading men of science, only one came from the artisan or peasant classes. Odin found that of 823 French men of letters, 65 per cent. came from the nobility and governing classes, 23 per cent. from the professions, 12 per cent. from the commercial and middle classes and 16 per cent. from the lower classes. The working classes outnumber the privileged classes a hundred to a thousand fold, but produce less than one quarter as many men of performance. If the working classes have equal ability and if they had been given equal opportunity, instead of a hundred scientific men of the rank of the foreign associates of the Paris Academy there would have been from four to forty thousand. It may be that the peasant and artisan classes in European countries are separated from the upper classes by an inferior heredity; but that is not the case in America. Five or ten generations back we all have ancestors of the same average social standing; any selection for ability within this short period must be slight and transient.

The emotional appeal to the sense of justice and sportsmanship for democratic equality of opportunity is compelling; the scientific argument for its wisdom is convincing. A hereditary aristocracy of wealth may for a time establish standards of manners and of fine living; it may foster science, literature and art. But its performance is trivial in comparison with what will be accomplished when each is given opportunity in accordance with his ability. This end has been more nearly approached in America than elsewhere. If it is asked why then we have not done more, the answer is that to have done this is the greatest of achievements. The more equal division of opportunity decreases the special privileges of a few—traditions and leisure are lacking. To educate a hundred million people by way of the yellow journal and the moving picture to what is of most worth in conduct and in life is of necessity a slow business. Measureless increase in wealth and knowledge will surely come. Whether the race can conduct its affairs better in riches than in poverty, by reason than by instinct, is the question confronting us.

Shortly before the discovery of America by Columbus and the instigation of the protestant revolution by Luther, printing was developed and movable types were reinvented, an advance in civilization only paralleled by the invention of the alphabet. It is difficult to conceive how there could have been some seventy-five universities throughout Europe before the time of the printing press. This appears to be an essential condition of general education and scientific progress as these are essential conditions of social and political democracy. It would take ten days to copy by hand the contents of a newspaper which is sold for two cents. All the people in America would need to spend their entire time to write part of what they now print. Unfortunately we print and read much that is unfit. It is a fundamental defect of our civilization that science has increased the means of production beyond our power to distribute fairly and to use wisely what is produced. The natural sciences and their applications have preceded the mental and social sciences and their applications. Investigation of the conditions of conduct and of its control is the great scientific problem of the future.

Raffael was born in the same year as Luther, two contrasted men, each typical of the country in which he lived and of the kind of work he did. Leonardo da Vinci and Michelangelo, both eminent in science as well as in art, Raffael and their contemporaries, under the patronage of the Medici in Florence and of the popes in Rome, carried the art of the Italian renaissance to its culmination,

perhaps to the beginning of its decline. Despotism and luxury were in control; but the genius of Italy did not fail. Galileo was born on the day on which Michelangelo died; art then yielded its supremacy to science. In the religion of positivism February the eighteenth, 1564, should be commemorated in the largest red letters of the saints' calendar.

Galileo in Italy, Descartes from France, and Hobbes in England are the founders of modern science; to them we owe the fundamental concepts of a mechanical world, the invariability of the relation between cause and effect, the complete lawfulness of nature. Galileo stands first both in time—he discovered the isochronism of the pendulum at the age of nineteen, five years before the birth of Hobbes and thirteen years before the birth of Descartes—and in performance. Hobbes and Descartes were primarily philosophers—lovers of wisdom or sophism as the case may be, devisers of castles without concern as to whether they stand on the rock or float in the air. Galileo was a man of science, so completely armed that the succeeding three hundred years have not seen his like.

Newton was born in the year in which Galileo died; scientific leadership passed from Italy to England. In that year, 1642, the conflict between King Charles and the parliament culminated in civil war. In answer to the parliament the King replied: "Should I grant these demands. . . . I should remain but the outside, but the picture, but the sign of a King." The parliament had its will, and Great Britain, though it remains a social aristocracy, has attained a democratic government more complete than ours. The ministers are directly responsible to the commons and to the people; there are no constitutions and courts to dominate the legislature.

Cromwell represented Cambridge in the long parliament; but the university, like Oxford, was loyal to the king. This has been the habit of universities, the natural homes of "lost causes and impossible loyalties." It is one of the dramatic ironies of history that the university, standing under the shadow of church and state, endowed by pious and aristocratic patrons for the education of the clergy and the upper classes, should by the inherent nature of knowledge subvert the old orthodoxy and the old privileges. It is only the metropolitan and provincial English universities and most of all our own state and urban universities that are directly responsive to the utilitarian democracy on which they depend. They suffer in dignity and in distinction; they lack traditions and leisure; but their crudeness and immaturity only display the vigorous youth to which the future belongs. It is not ignoble to follow in the steps of Milton, the radical, who abandoned his poetry for twenty years to engage in the rough struggle for liberty. As he says to himself: "Ease and leisure was given thee for thy retired thoughts out of the sweat of other men." But he reflects that if he had been as dumb as a beast when the cause of God was to be pleaded, he would have been that which his own brutish silence had made him.

England had enjoyed her great Elizabethan era in poetry and in adventure; a scientific period followed. Bacon drew up a code of scientific procedure with the authority of a lord chancellor; Hobbes made mechanics the basis of his philosophy. At the same time nature was studied at first hand. Gilbert's work on the magnet was produced contemporaneously with Hamlet, Macbeth and Lear. Harvey's work on the circulation of the blood appeared five years after Shakespeare's words were printed:

> As dear to me as are the ruddy drops
> That visit my sad heart.

Sydenham, Hooke, Grew, Boyle and others carried forward scientific investigations. Then came Newton, whose

primacy in science can only be challenged by Aristotle and Galileo.

It was by no means an age of liberty and democracy; Cromwell ruled as a benevolent tyrant; England was ready to take back its Stuarts and when they proved intolerable to exchange them for Hanoverian princes. In France, Louis XIV and Richelieu lorded it with a high hand. The states-general were not summoned from 1614 until the eve of the revolution. The court and the nobility were saturated with extravagance, folly and sin; the people were oppressed intolerably. In Germany the thirty years war reduced the population to less than one half. In a crude and small way the courtlets and princelings followed Versailles. There was no representative or parliamentary government; the people were there only to be taxed and killed. Conditions were worse, if that be possible, in southern Europe. The Italian provinces, ruled by despots, were the playthings of the courts north of the Alps. In Spain the period of letters and art, of Cervantes and Velasquez, was not followed by a period of science. The inquisition burned at the stake 30,000 victims and imprisoned ten times as many.

The Protestants in Austria, the Huguenots in France, the Jews in Spain, were killed or driven away; a suppression and redistribution of intellect and character was effected that lasts to the present day. Of special interest to us is the migration of Puritans and other dissenters to America. They were selected men and women, and the country was largely peopled with their descendants. There was a second selection for independence and ability when the central states were settled by migrations from New England, and we have here a population of remarkable potentiality, most of its Lincolns mute and inactive through circumstances.

An age of despotism and oppression is not necessarily inimical to literature, art and science; nor is an age of freedom and democracy necessarily friendly to them. On the contrary, the lavish extravagance of kings, princes and nobles has often given opportunity for a display of genius, while a sober and righteous people may look askance at such things. But luxury consumes its children, whereas democracy and equal opportunity may prepare the ground to produce flowers as well as fruits. In the course of the seventeenth and eighteenth centuries, Italy and Spain, France and England, seemed to fail in genius as well as in freedom. There was a rough exhibition of democracy and equal opportunity in that any adventurer might become a general; a prelate, or a courtesan from any class of society might rule the court. Above all there was working in the mass of the people the ferment leading to the great movement of democracy and science of the nineteenth century. In the north Prussia and Sweden were preparing for their parts, and semi-barbarous Russia was emerging to the destiny not yet fulfilled. At the same time far-off America was laying the foundation of its present civilization. Prediction is futile, but it is also harmless, so there is no objection to fancying that the United States, Russia and China will play the chief parts in the history of the coming century.

These reflections began by dating science and democracy from the discovery of America by Columbus; with unabated patriotism I venture to date recent science and democracy from July 4, 1776. Certainly the discovery of America and the declaraton of independence are not so much causes as signs of the two greatest world movements. But for us in this country they mark turning-points or starting-points in history. The modern period has given us in art, the music of Bach, Beethoven and Wagner; in literature, the novel; but all other human achievements pale in the blinding light of science and democracy.

Let us once again call to mind that science with its applications is the cause of

democracy, while the debt of democracy to science remains to be paid. In a single century science has doubled the length of human life and reduced to one fourth the manual labor required from each. The heritage which science has conferred on democracy has been but partly and imperfectly used. Wealth and opportunity are still distributed with scandalous disregard of the principles we profess. If we still kill one fourth of our children in some places; if we still give nine tenths of our boys and ten tenths of our girls no equality of opportunity; if we permit not only men, but also children and women, to work ten hours or more a day in unhealthful occupations; if we allow tariffs and trusts to take from the poor to give to the rich; all this is not the fault of science. It is now the business of democracy to give science the chance to increase to the limit the economy of production and the conservation of health, while at the same time directing its chief care to developing the sciences concerned with conduct.

However artificial it may be to date the modern movement of science and democracy from the declaration of independence followed by the French revolution, it is less so than to date it from the calendar beginning of the nineteenth century. Voltaire and Rousseau, having made straight the way for the French revolution, died in the same year, just after the beginning of our revolution. Goethe was born in 1749, Schiller and Burns ten years later, Wordsworth in 1770. Our revolution was academic: it but confirmed the existing state of affairs and passed from precedent to precedent; Washington, Jefferson, Franklin and Adams were only rebels by force of circumstances; our constitution guards and limits the freedom of the people. The French revolution was melodramatic and led directly to Napoleon.

But contrasted as they are, the American revolution and the French revolution ended forever the old disorder of the world. We complain pretty continuously about our social and political institutions —and sometimes we try to improve them. We may well look with hope to the future when we recall what science and democracy have accomplished within two hundred years—since the time when the entire population of a country might be reduced to half by war, pestilence and famine, since a convent or a king's court might be a brothel, since a French noble in the course of the chase might kill a peasant to warm his feet in the entrails, since even in this country puritans might burn witches and cut off the ears of Quakers.

With advancing political and social democracy there was an extension of science as well as a renaissance of letters. Unlike art and letters science has moved forward continuously in almost every direction and in almost every country. Italy has not again produced a Galileo, nor England a man like Newton, unless it be Darwin. But the foundations that they laid have been built upon in a way that does not hold for the art of the Italian renaissance or the drama of the Elizabethan era. Newton, Huygens and Leibnitz had successors to carry forward their work and to open new lines of which they did not dream. In spite of the marvelous accomplishment of Newton, Laplace, born twenty-two years after his death, carried celestial mechanics to even greater perfection. Kant and Laplace introduced, though somewhat incidentally, the conception of cosmic evolution. Science made quantitative by Galileo and Newton then became also genetic; these are the two great methods of science. The doctrines of the conservation of energy and of organic evolution have given complete exemplification of the quantitative and of the genetic methods.

In so far as the advancement of science and the progress of democracy are movements important to the world beyond all

others, knowledge of the causes of these movements is of more worth than any other knowledge and the power to control them is of greater consequence than any other power. It is our business to obtain this knowledge and to acquire this power. My argument is that science has been the cause of democracy. If wants are very simple, it is possible to have a kind of equality of opportunity and of resources, as among the lower animals and savages. When conditions become more complicated, society is thrown into a patriarchal, or feudal, or despotic, or oligarchic system. The material resources are not sufficient to provide adequately for all; the stronger seize on them, and the many must toil in ignorance and poverty in order that a few may have knowledge, leisure and luxury.

But with the applications of science to industry and commerce, to the prevention of disease and premature death, it again becomes possible to provide equality of opportunity and adequate resources for all. The period of childhood and youth can be used for universal education, so that each is given the chance to prepare for the work for which he is best fit, and at the same time to obtain the wider outlook that enables him to take his share in a democratic government and to appreciate the things in life that are of most worth. Science has made political and social democracy possible and has given us so much of it as we have. It should be the chief concern of democracy, in order that it may become secure and complete, to promote the further extension of science.

An aristocracy of wealth and leisure has been in the past more favorable than a democracy to science and art. There are in it those who are able to answer the call of science—think what the world would have lost if Darwin had not possessed inherited wealth—and appreciation and honors are given as rewards. But democracy will surely in the future do more for science; it will give not only to a small class but to every one the opportunity to use the talent that he has, and it will find means to reward scientific work, not by titles and honors and positions, but by the good democratic method of paying for work what it is worth.

The great obstacle to the advancement of science is that research can not be undertaken as a profession, each man earning his living by his work and being rewarded in proportion to its value. The physician is paid for curing and even for killing his patients; but not for the research and discovery which have done more to diminish suffering and disease than all the practice. The engineer is paid for the particular work he does, but scarcely for the improvements in method which make further work cheaper and better. Scientific research has been dependent on the instinct of curiosity and of play directed to its highest end; organized society has done nearly as much to thwart this instinct as to reward it. The work which is of benefit to all the people should be paid for by all the people. Monopolies, which make it possible to charge more for a service than it costs, must be controlled by the government; scientific advances and other services rendered to all without cost to them must be rewarded by the state, which only has the power to collect the value of the service from those benefited.

Something has been accomplished. Among the comparatively small number of powers assigned to the Congress by our Constitution is "To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive rights to their respective writings and discoveries." Municipalities, states and the nation are learning the wisdom of employing scientific experts both in economic work and in pure science. But since the foundation of the universities of Salerno, Bologna, Paris and Oxford, the natural home of scientific research and creative

scholarship has been the university. This was most completely exhibited in the German universities of the nineteenth century, which gave that country the primacy in science that it holds.

Men were chosen for university chairs as a reward for research work and as an opportunity for further work. The selection was fairly democratic, for if a student could follow a university course his future career depended on his ability. If he succeeded he became a member of an aristocracy of scholars. In America we have not had a leisure class, as in England, interested in science, nor until the last quarter of the last century universities, as in Germany, in which research work was cultivated. These conditions explain the backwardness of the country in science. We can not afford to keep a leisure class for certain desirable by-products; it is more economical and in every way better to pay directly for our science. We are now beginning to do so. Our government spends more than any other on its scientific work and the quantity is greater. We may hope that the lack of distinguished quality is not due to inferior racial genius, but to inadequate rewards, appreciation and opportunity. Democracy does not mean equal mediocrity of all, but performance by each in accordance with his ability.

Of our thousand leading men of science, only eleven may be classed as amateurs; 106 are in the government service; 738 are engaged in teaching, nearly all in a few universities. Our scientific research is thus in the main dependent on the universities as has been the case in Germany. To them we must give credit for the work that they have made possible; on them must be placed the responsibility for our failure to do more. We may hope that the comparative sterility of our universities is in the main due to the recentness of their establishment, and to the stupid methods of autocratic control that have resulted from newness and haste, rather than to lack of genius in the people. We may look forward to the time when the numbers of students, the cost of buildings and the complexity of the administrative machinery will be subordinated to the personality and the performance of great men.

The discovery of America marked a new period for science and for democracy; the foundation of the nation reflected the progress of knowledge and of liberty; for a third time it is possible to associate our country, if only by way of coincidence, with their further advance. Darwin and Lincoln were born on the same day. At nearly the same time the "Origin of Species" was published and the slaves were emancipated. Freedom of thought and freedom of action received together their complete expression. Never again will truth be permanently suppressed; never again will men be held in legal slavery.

With the ebb and flow of the secular tides, music, poetry and art may blossom and then wither; the family, the church and the nation may pass as they have come; but the stream of science and of democracy will flow ever onward, enlarged by every spring and brook from all the land. They will surely complete their perfect work. To every child will be given his heritage of happiness and opportunity; men and women will find the work for which they are fit and the reward that they deserve. The wealth now wasted on armaments, futile luxuries, idleness, preventable disease and crime will be devoted to new advances in science which in turn will provide new opportunities. To all nations and to all men will be given according to their needs; from all will be received according to their ability.

The swords we know will then at last be turned to reaping tools;
The cross we know, the world's dead cross, will bud and blossom then.

THE PROGRESS OF SCIENCE

SCIENCE SPEAKS AT INDIANAPOLIS

In certain respects the annual meetings of the American Association for the Advancement of Science are the most important scientific conventions held in the United States and perhaps in the world. The meeting of the association that will be held in Indianapolis, Indiana, from December 27 to January 1, inclusive, will illustrate the statement.

If mere size were a proof of importance the meeting would rank very high, for within six days more than 1,250 addresses and papers will be presented in 225 different programs. If wide geographical distribution of those attending the meeting were taken as the criterion of importance, it would still rank high, for scientists will assemble at Indianapolis from nearly all parts of North America. If diversity of subjects considered were the basis for judgment, the meeting would rank superlatively high, for its programs cover essentially all the wide field of pure and applied science. They range from the abstractions of pure mathematics to remedial reading for the dull; from cosmic rays to the growing of potatoes; from prehistoric Indians to current economic theory.

The Indianapolis meeting has, however, much better claims to being important than mere size or diversity of interests. To a considerable extent its programs are concerned with coordinations and integrations of various fields of science. A century ago science consisted largely of *natural philosophy* and *natural history*. Having become by that time thoroughly impregnated with confidence in the orderliness of nature and the soundness of the experimental method, like a fertilized ovum it rapidly divided and subdivided into more and more branches, each growing with all the vigor of its parent. With this subdividing of science there have inevitably developed specializations roughly analogous to those in growing organisms. Although a specialized organ may be, for limited purposes, much superior to one whose functions are more general, yet it is much more dependent upon related organs. Similarly, the more specialized a science is the more dependent it is upon other sciences.

The scientific programs of the meetings of the association are organized by its sixteen sections, each representing such a scientific field as physics, chemistry or the botanical sciences, and by its 163 affiliated and associated societies. Of the affiliated societies, eighty-two are strictly professional scientific societies and thirty are academies of science. Of the associated societies, twenty are professional scientific organizations. Forty-one of these affiliated and associated societies are meeting with the association in Indianapolis. The combined membership of these societies (including duplications) is now approaching a million. These figures indicate the amazing growth of science within the lifetime of the association and the magnitude of the problem of coordinating and integrating it for the benefit of society as a whole and of human beings as individuals.

There are two ways in which meetings of the association promote correlations among the sciences. One is the unparalleled opportunities they provide for scientists in different fields to mingle with one another and to exchange ideas. As all scientists know, there is more than a grain of truth in the definition of a specialist as being one who knows more and more about less and less. Specialists are necessary, and so are integrationists (to coin a word) if science is to realize its high possibilities. The meetings of the

association tend to make integrationists out of specialists.

Another and more direct way in which meetings of the association promote syntheses of science is through symposia. For example, the Section on Chemistry has organized a symposium on "The Applications of Surface Chemistry in Biology," which will be participated in by five distinguished scientists. The purpose of this symposium is to examine and explain the fundamental processes involved in the metabolism of living organisms. The Section on Geology and the Geological Society of America have organized a joint symposium on "Petroleum Geology of the Illinois-Indiana Basin," a subject having not only scientific but economic interest.

In the symposium on "The Endocrines as Related to Behavior" psychology, physiology and medicine are concerned. The one on "The Relationships between Insects and Plant Diseases" involves entomology, botany, horticulture and agriculture. "The Maya Civilization" symposium is sponsored jointly by the Section on Historical and Philological Sciences and by the History of Science Society. The chemists, agronomists and horticulturists are uniting in a discussion of the recently discovered effects of minor chemical elements on the growth of plants. Psychologists and educationists (to coin another word), agriculturists and botanists, plant physiologists and horticulturists, chemists and physicists, zoologists and geneticists and other cooperating groups will hold joint meetings or have joint luncheons or dinners. The inspiration and broadening effects resulting from these minglings of scientists can not be easily overestimated.

There is another somewhat different type of symposium that is illustrated by those organized by the Section on the Medical Sciences. The distinguishing characteristic of these symposia is that they present in an organized form essentially all that science now knows on some important subject. For example, at the Atlantic City meeting a year ago the subject was the cancer problem, all phases of which, from that of heredity to the therapeutic effects of radium and x-rays, were treated by eminent authorities. At Denver last summer the subject was the class of micro-organisms that cause tuberculosis, leprosy and a few other diseases. In Indianapolis, it is syphilis. The cancer symposium has been published in a fine volume, and the one presented in Denver is now being printed.

It is easy to overlook the fact that science is the most powerful force operating in the world. As astonishing as are its direct technological applications to living, they are probably much less important than their impacts upon the economic social and governmental organization of society. The Section on Social and Economic Sciences has organized for the Indianapolis meeting the first of a series of conferences (symposia) on the broad subject of "Science and Society." It is inspiring to find scientists through their broadest and most influential society setting themselves seriously to examining the effects of the impact of science upon society. There can be little doubt that along that road lies the most desirable goal for civilization.

Finally, the meetings of the association represent the spirit and conscience of science. Through press reports and over the radio its voice reaches throughout the land. It calls for cooperation among men, not strife; it exalts freedom of the spirit, not arbitrary control; it promises heaven on earth, not in a vague beyond. That it permeates and enriches all the deep currents of life is illustrated by the subject of the retiring presidential address of Dr. Edwin G. Conklin—"Science and Ethics."

F. R. Moulton,
Permanent Secretary

SYMPOSIUM ON BIOPHYSICS

A SYMPOSIUM on biophysics was held on November 4, 5 and 6 in Philadelphia. The first large meeting devoted to this borderland field, it was sponsored by the American Institute of Physics in cooperation with the Eldridge Reeves Johnson Foundation for Medical Physics of the University of Pennsylvania. The sessions were held in the University Museum.

The meeting served two principal purposes. It marked a stage in the progress of those fields of biological research in which the methods and results of physical research play a large rôle, and it provided a forum where research men of this field might meet. The program reflected this two-fold character. The first two days were devoted to invited papers by twelve leaders of research. Their topics ranged from those almost exclusively of interest to biologists to others which are of as great interest to the pure physicist as to the biologist.

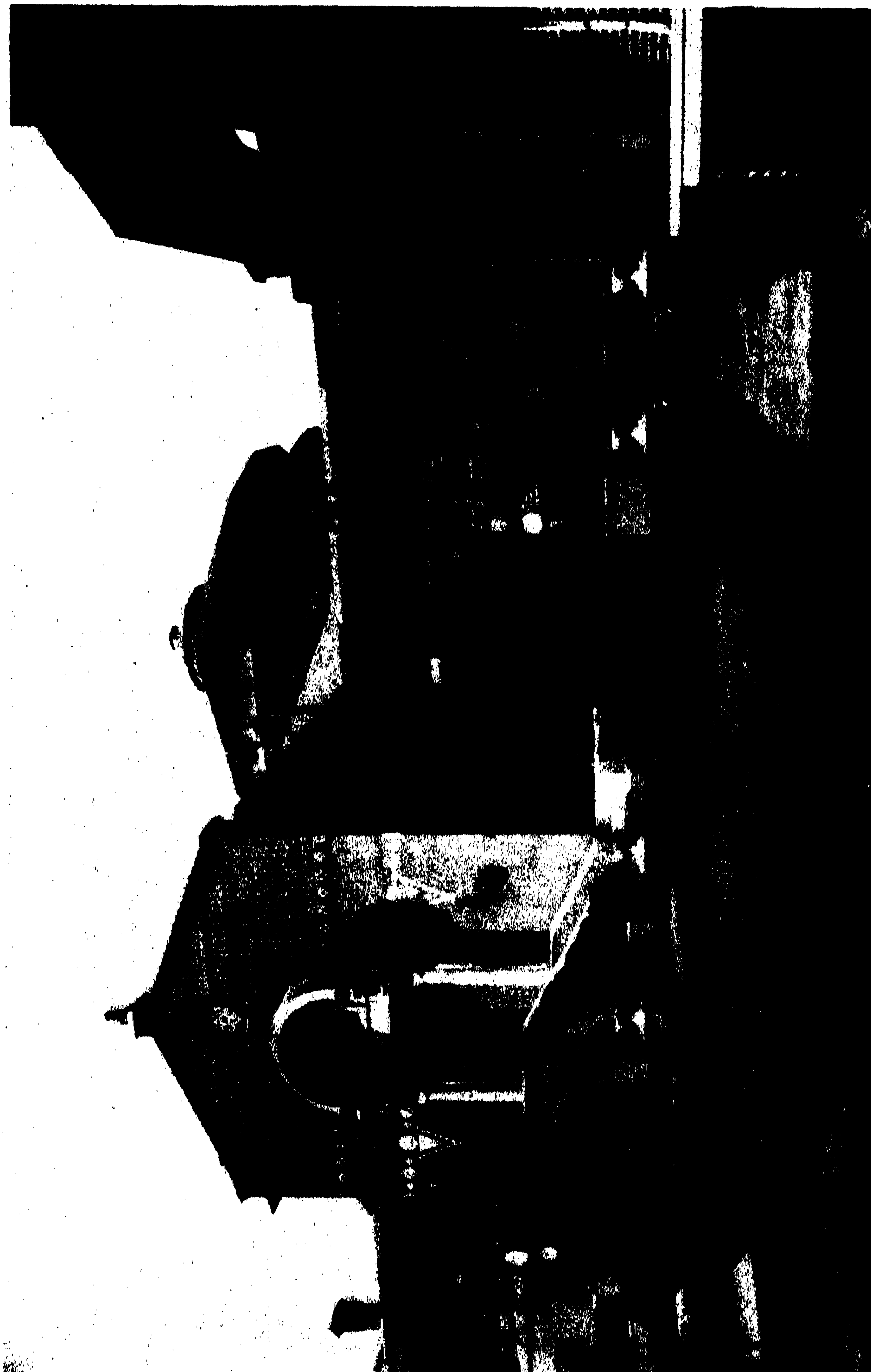
In the evenings of these two days, Dr. Irving Langmuir presented the first two of his Johnson Foundation lectures on "Monolayers and Multilayers and their Applications to Biological Problems." The third day of the meeting consisted of two parallel sessions in which some thirty short papers were presented on the subject of current researches and their results.

The meeting was opened by Dr. John T. Tate, chairman of the American Institute of Physics, who introduced Dr. Alfred Stengel, vice-president in charge of medical affairs of the University of Pennsylvania. Dr. Tate, in his introduction, referred to the desire of the institute to provide increased opportunity for the development of those fields of allied sciences in which physicists can make contributions of direct value. He referred to the admirable research program of the Johnson Foundation, stating that it was this and the general activity in biophysics in and near Philadelphia which led the institute to choose that city for the meeting. Dr. Stengel welcomed the symposium for the university and traced the history of the Johnson Foundation in its relation to the growth of biological research with the aid of the methods of physics.

The latter theme was expanded by the next speaker, Dr. Detlev W. Bronk, director of the Johnson Foundation. Dr. Bronk referred to the subject-matter of the field, but placed his emphasis on its position in the totality of human interests and the general need for integration of the subdivisions of science. While there is general recognition that the field exists and is important, its development is hampered. Too few students learn physics and biology together from the ground up. There are too few positions of sufficient attraction open for them to fill. Dr. Bronk expressed the hope that more foundations in biophysics would come into existence, that every large physics departments would have one or more staff members primarily interested in the biological aspects of physics, and that biological laboratories, hospitals and medical institutions would see that the services of competent physicists were directly available to them.

Dr. E. Newton Harvey, of Princeton University, spoke on "The Physical Properties of Protoplasm," although, as he said, his subject was really necessarily the cell as a whole. Modern biophysical study of the cell rests on the techniques of classical physics and microscopy. By observed motions, displacements and distortions, occurring as a result of known forces, such as centrifugal forces, the viscosities and the tensions at the surfaces of cells can be found. Dr. Harvey illustrated his paper with slides and with motion pictures showing cells elongating and breaking apart in the field of a centrifuge-microscope.

Dr. M. H. Jacobs, director of the Marine Biological Laboratory at Woods Hole, spoke on "Diffusion Processes in Living Systems." He referred to the great mystery of living organisms which can use diffusion to maintain and de-



THE UNIVERSITY OF PENNSYLVANIA MUSEUM, WHERE THE MEETINGS OF THE SYMPOSIUM WERE HELD

velop structure, although fundamentally diffusion is a process by which molecules pass by reason of simple probabilities from the organized to the unorganized. The major point of attack on the problem presented is on the vertebrate red blood corpuscle or erythrocyte. Dr. Jacobs referred to researches and results achieved on the behavior of their plasma membranes in passing or stopping materials of various kinds.

Dr. Herbert S. Gasser, director of the Rockefeller Institute for Medical Research, speaking on "Electrical Signs of Biological Activity," took as his principal example the behavior observed by means of electrodes within and without the surface films of nerve fibers. The sharp oscillographic spikes of potential detected indicate the mechanisms involved in nerve communications and have enabled the beginning of a theory of nervous activity to be set up which is proving very fruitful as a guide to further experimental work.

Dr. W. Mansfield Clark, of the Johns Hopkins Medical School, spoke on "Potential Energies of Biologically Important Oxidation-Reduction Processes." His paper was an excellent example of integrated fields of science as it was of interest in the three fields of biology, chemistry and physics. It considered the application of thermodynamics to the living cell, showing how this form of logic could often rule out conceivable mechanisms on the grounds of extreme improbability.

Dr. Francis O. Schmitt, of Washington University, speaking on "Optical Studies of the Molecular Organizations of Living Systems," referred to the necessity of understanding the configurations and orientations of the protein and lipoid molecules which go to make up living protoplasm. His paper dealt with studies of this problem using polarized light and x-ray diffraction analysis.

Dr. L. H. Germer, of the Bell Telephone Laboratories, spoke on "Electron Diffraction Methods of Studying Organic Films." This technique, important in the study of metallic and other crystalline surfaces, is applicable to thin biological materials. Dr. Germer described the techniques he has developed and indicated the fields of use and precautions to be observed.

Dr. Wendell M. Stanley, of the Rockefeller Institute for Medical Research, spoke on "The Biophysics and Biochemistry of Viruses." He referred to the declining view that viruses are living things, emphasizing their size and other properties which are characteristic rather of chemical molecules. He described recent researches in which, with the ultracentrifuge, the tobacco mosaic virus has been isolated in crystal form. This isolated substance constitutes material for researches which may lead to the practical production by purely chemical means of substances having immunizing properties.

Dr. Selig Hecht, of Columbia University, spoke on "Photochemistry of Vision." He traced the development of early ideas, their failure, owing to inadequate knowledge of photochemistry, and their present revival on the basis of better knowledge. His paper dealt with theories based on quantitative experiments on that stage in vision wherein light reacts with a sensitive element which, undergoing change, is enabled to activate optic nerve fibers.

Dr. Wallace O. Fenn, of the University of Rochester, spoke on "The Mechanics of Muscular Contraction." He described physical apparatus and mechanical reasoning which enable extensive studies of muscular mechanics to be made on living human subjects. The results indicate many of the properties of muscles as they vary under different conditions such as degree of extension. Such results must be useful in the study of the fundamental mechanism of muscular contraction.

Dr. L. A. DuBridge, of the University of Rochester, speaking on "Some Aspects of Nuclear Physics of Possible Interest in Biological Work," referred

DR. IRVING LANGMUIR
ASSOCIATE DIRECTOR OF THE RESEARCH LABORATORIES OF THE GENERAL ELECTRIC COMPANY.

principally to the neutron and to materials possessing induced radioactivity. The neutron rapidly imparts kinetic energy to the hydrogen atoms in biological materials, and these then produce intense local ionizations, different in density from that produced by beta rays, gamma rays or x-rays. The common elements, rendered radioactive, may have therapeutic value, but their greatest immediate use is in tracing the course of chemicals through biological processes.

The Saturday sessions of contributed research papers proved of no less interest than the invited papers referred to, large groups attending each of the sessions.

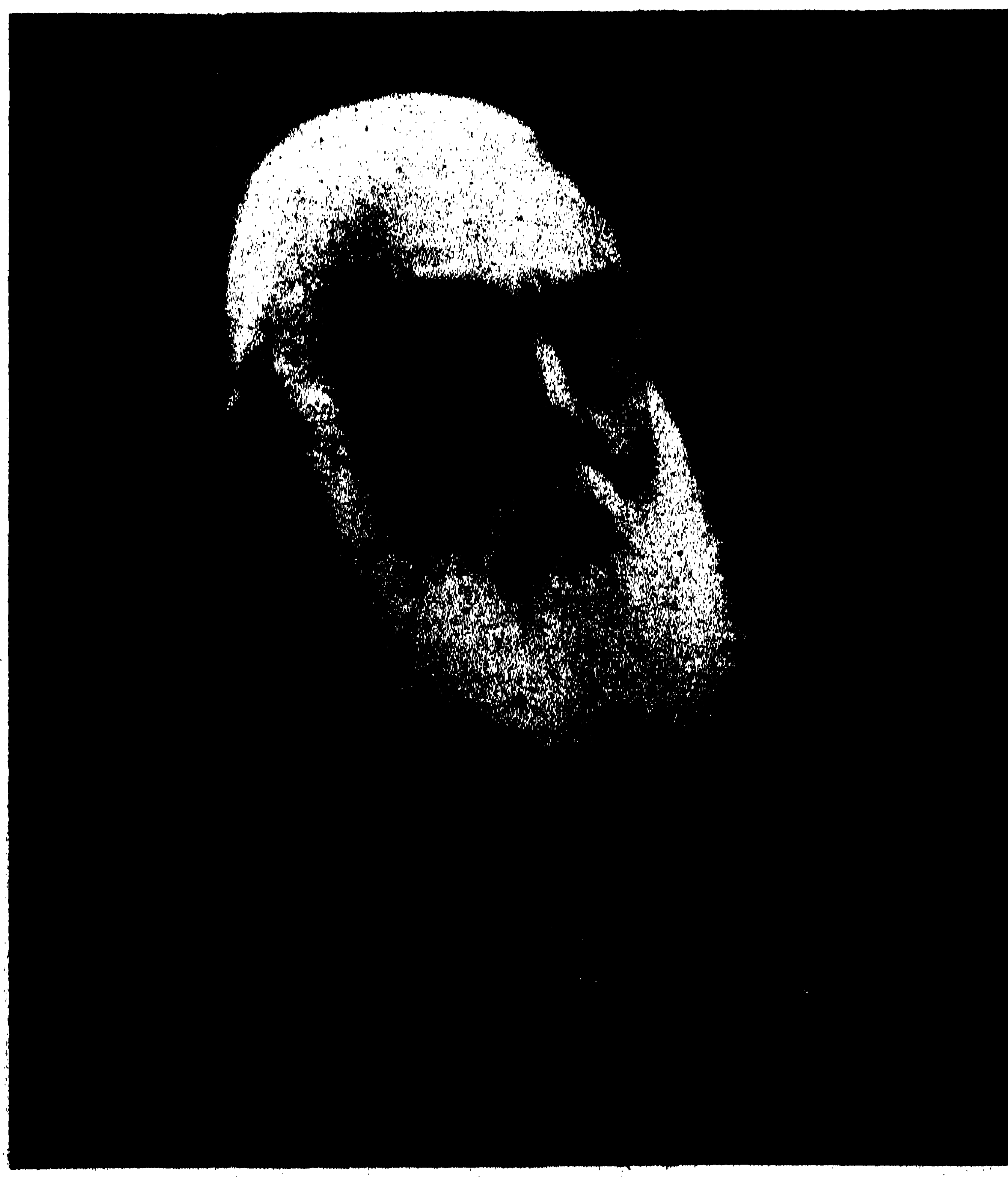
The symposium papers will be published for the most part in the *Journal of Applied Physics*, of which copies may be obtained from the office of the American Institute of Physics at 175 Fifth Avenue, New York. This symposium is the second of a series on fields of application of physics sponsored by the institute. The first dealing with physics in metals was held in January, 1937, at Cambridge, Mass. It is planned to hold another in the near future on physics as applied to automotive transportation.

H. A. Barton

THE CENTENARY OF THE NEW YORK STATE MUSEUM

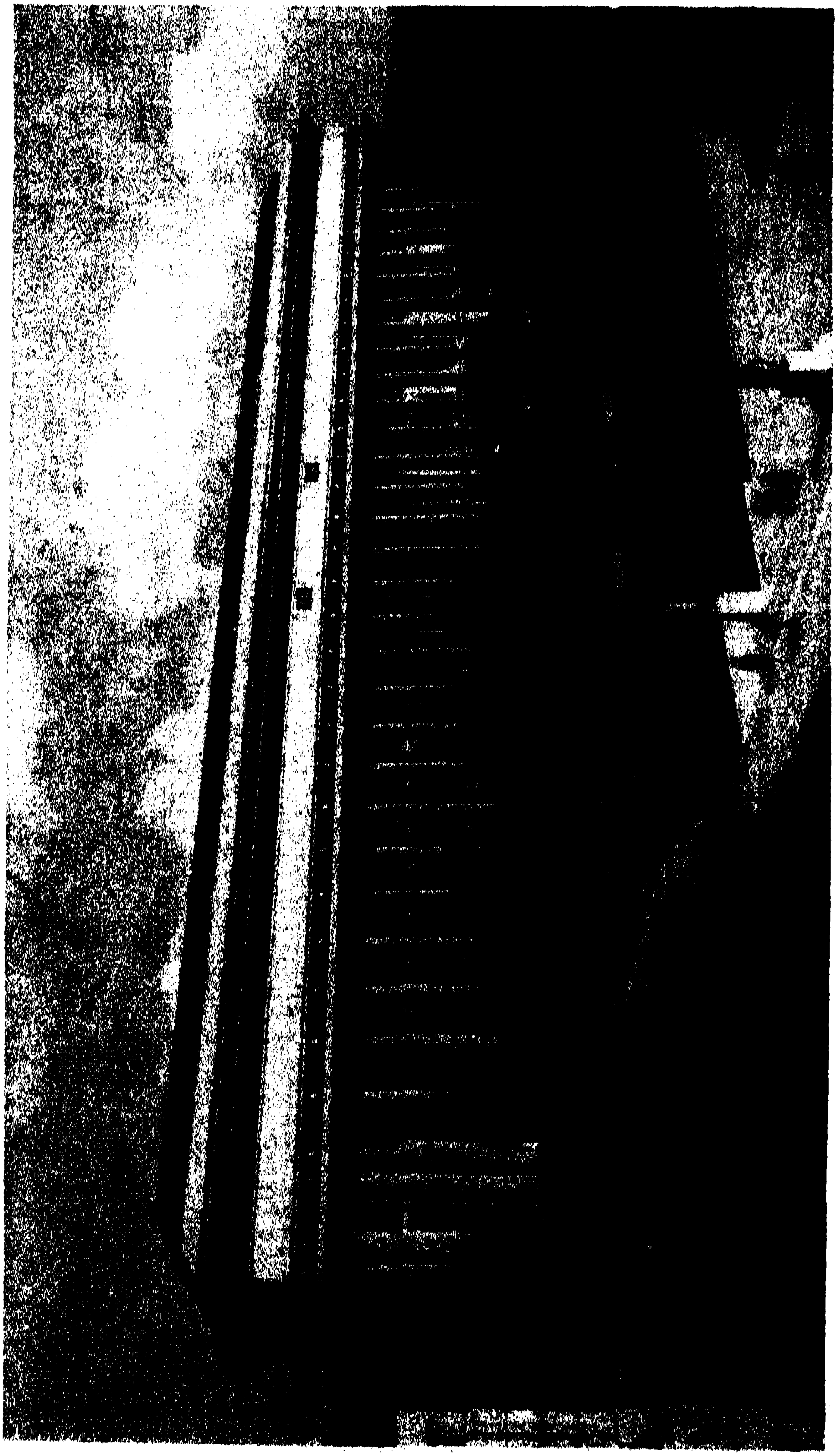
On April 15, 1836, the Legislature of New York inaugurated a state geological and natural history survey. This developed one of the first inventories of the natural resources of any state, and thus New York was one of the first states to recognize that such scientific studies were a public function. It was at the same time the first scientific agency of the New York State government. The work of this agency, under various names, consolidations and enlarged functions, many years ago became officially known as the Division of Science and State Museum and is a part of the State Education Department at Albany.

The work of James Hall, John Torrey and their associates made a unique record for the early geology, botany and zoology of the state. Later the work accomplished by Dr. Asa Fitch, Dr. J. A. Lintner and Dr. E. P. Felt in entomology, Dr. Charles H. Peck for the fleshy fungi, Dr. John M. Clarke and Dr. Rudolf Ruedemann in paleontology, and Lewis H. Morgan and Dr. W. M. Beauchamp in Indian ethnology and archeology, has been outstanding. From its inception the institution has been primarily a research organization, and its extensive publications, both technical and popular, have been its major achieve-

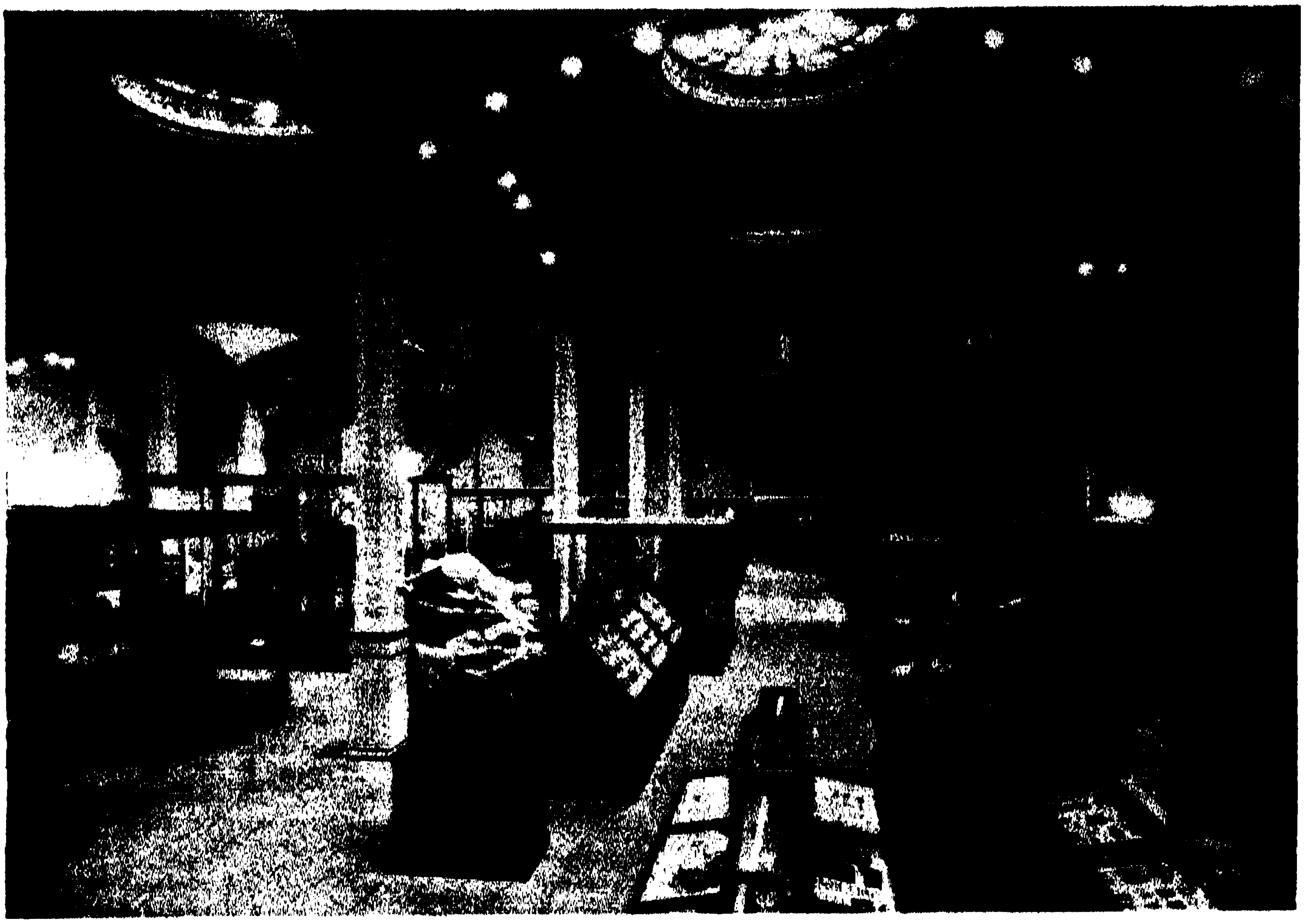


JAMES HALL

GEOLOGIST OF THE STATE OF NEW YORK AND FIRST DIRECTOR OF THE NEW YORK MUSEUM. THE PHOTOGRAPH WAS TAKEN IN 1896 WHEN HALL WAS EIGHTY-FIVE YEARS OF AGE.



THE NEW YORK STATE EDUCATION BUILDING
IN WHICH ARE THE STATE MUSEUM AND THE DIVISION OF SCIENCE.



THE ZOOLOGY HALL OF THE NEW YORK STATE MUSEUM

ment. Notable exhibits have also been made. In normal times its exhibition halls are regularly visited by about 200,000 visitors, including thousands of pupils and students from schools and colleges.

With the passing of the years the field of activity has been expanded beyond that of the sciences to include the history and art of the state, although these fields have not been adequately developed.

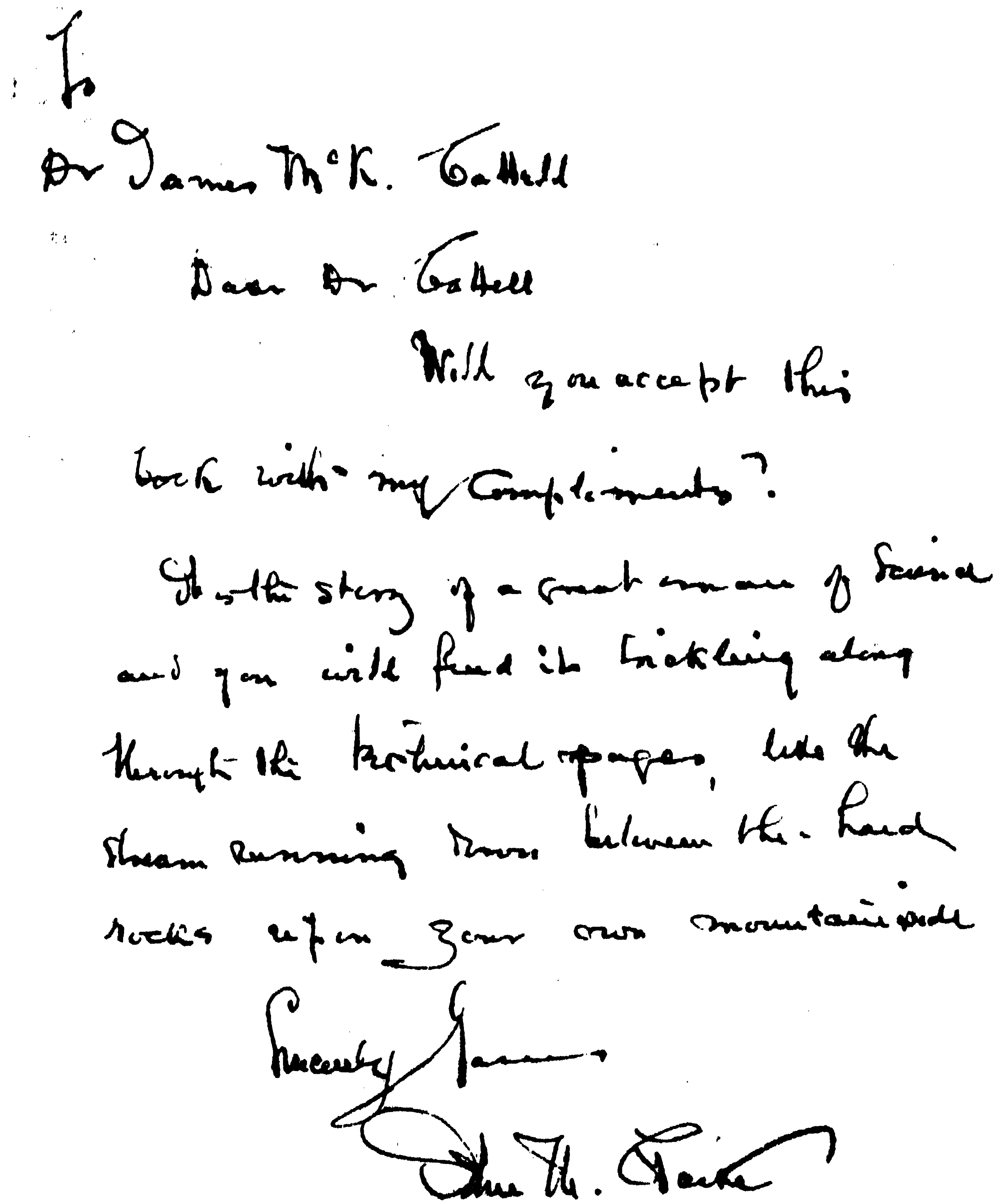
In commemoration of its centenary on April 15, 1936, the State Board of Regents decided to devote its seventy-third annual convocation on October 15, 1937, to this anniversary. The general theme of an anniversary has been aptly expressed by Dr. C. Stuart Gager as follows:

> But what is the point and purpose of recognizing an anniversary? . . . It is not so much to celebrate past achievement, but to reveal to the world the nature of the institution; for those in charge of it to clarify and possibly to restate their ideals in the light of the wisdom gained by past experience, and with a clear vision of future and larger accomplishments, made possible by new conceptions, new deeds, new methods and techniques, new resources and new enthusiasm.

In addition to this aim it was also intended to include emphasis on cultural, higher and synthetic values of science.

The speakers at the afternoon session were: Dr. John C. Merriam, president of the Carnegie Institution of Washington, whose address was on the "Influence of Science upon Appreciation of Nature"; Dr. C. Stuart Gager, director of the Brooklyn Botanic Garden, "The New York State Museum: One Hundred Years Young," and Lewis Mumford, author of "Technics and Civilization" and of a newly announced book, "The Culture of Cities," on "Regional Survey: Science for Citizenship."

The evening session was devoted to the relation of science to democracy. This was developed by Dr. Arthur E. Morgan, chairman, Tennessee Valley Authority, who spoke on "The Relation of Electricity to Social Policy," and Mr. Waldemar B. Kaempffert, science editor, *New*



To

Dr James McK. Cattell

Dear Dr Cattell

Will you accept this book with my compliments?

It is the story of a great man of science and you will find it trickling along through the technical pages, like the stream running down between the hard rocks upon your own mountain side

Sincerely yours

John M. Clarke

INSCRIPTION

IN A PRESENTATION COPY OF THE LIFE OF JAMES HALL BY JOHN M. CLARKE, WHO WAS DR. HALL'S SUCCESSOR AS DIRECTOR OF THE STATE MUSEUM.

York Times, whose address was "Science and Democracy."

Honorary degrees of doctor of science were conferred by Dr. Frank Pierrepont Graves, president of the University of the State of New York, upon Dr. John C. Merriam, president of the Carnegie Institution, and upon Dr. Alexis Carrel, of the Rockefeller Institute for Medical Research.

A chronological sketch of the history of the state museum and its antecedents has been prepared by the members of the museum staff, and has been published as a part of the anniversary celebration.

CHARLES C. ADAMS,
Director

DIVISION OF SCIENCE AND
STATE MUSEUM

THE WORK OF PROFESSOR SZENT-GYORGYI, RECIPIENT OF THE NOBEL PRIZE IN PHYSIOLOGY AND MEDICINE

DR. SZENT-GYÖRGYI served in the Medical Corps of the Hungarian Army during the world war. After the war he became interested in biological oxidation and examined the various oxidation systems one by one in order to explain the reaction mechanism which was involved. A new oxidation system was brought to light when the adrenal gland was examined and subsequently a new and very interesting substance was shown to be present. Eventually this compound was isolated in pure crystalline form and was shown to possess the formula $C_6H_8O_6$. This same compound was then found to be widely distributed in nature, especially in the rapidly growing part of plants, such as lawn grass, the new shoots of grain, iris leaves, and so forth. The compound was named hexuronic acid, and a serious attempt was made to prepare sufficient amounts for its identification. This attempt brought Szent-Györgyi to the United States in the winter of 1929, at which time a quantity of hexuronic acid was isolated from adrenal glands at the Mayo Clinic, Rochester, Minnesota.

In 1930 Szent-Györgyi was appointed director of medical chemistry at the University of Szeged, Hungary. During the

PROFESSOR A. SZENT-GYÖRGYI

following years he carried on an investigation of the chemical and biological properties of hexuronic acid and in the spring of 1932 Szent-Györgyi and Svirbely established the fact that hexuronic acid was vitamin C. At the same time Dr. C. G. King and W. A. Waugh, of the University of Pittsburgh, showed that a crystalline compound which they had isolated from lemon juice and which was known to possess anti-scorbutic properties was identical with the compound hexuronic acid which had already been described by Szent-Györgyi. The identification of the chemical nature of vitamin C inaugurated innumerable investigations which have been concerned with the distribution and function of this important vitamin.

Szent-Györgyi found that the best natural source of vitamin C was the peppers grown in Hungary, and from this material several kilos of vitamin C were prepared in pure crystalline form. This enabled Haworth and Karrer to complete the identification of the vitamin, which in turn has permitted the development of methods for its synthetic preparation. It is now being prepared on a large scale from glucose.

Szent-Györgyi observed that some patients with purpura were relieved by the juice of peppers or of citrus fruits but not by pure vitamin C. Further investigation indicated that there is present in citrus fruits a second compound which has to do with the permeability of capillaries. This substance appears to belong to the family of flavons and has been named vitamin P from its relation to permeability. The symptoms of scurvy appear to be due to a lack of both vitamin C and vitamin P.

In addition to the work on vitamin C, Szent-Györgyi has carried on extensive studies in relation to the coenzyme involved in the oxidation of lactic acid and finally in regard to the significance of succinic, fumaric and oxalacetic acids in biological oxidations. The results of Szent-Györgyi and his coworkers have shown that these dibasic acids are involved in biological oxidation, probably as catalytic agents. One of the most surprising results of this work has been the observation that acidosis in patients with diabetes may be relieved by the administration of succinic acid.

E. C. Kendall

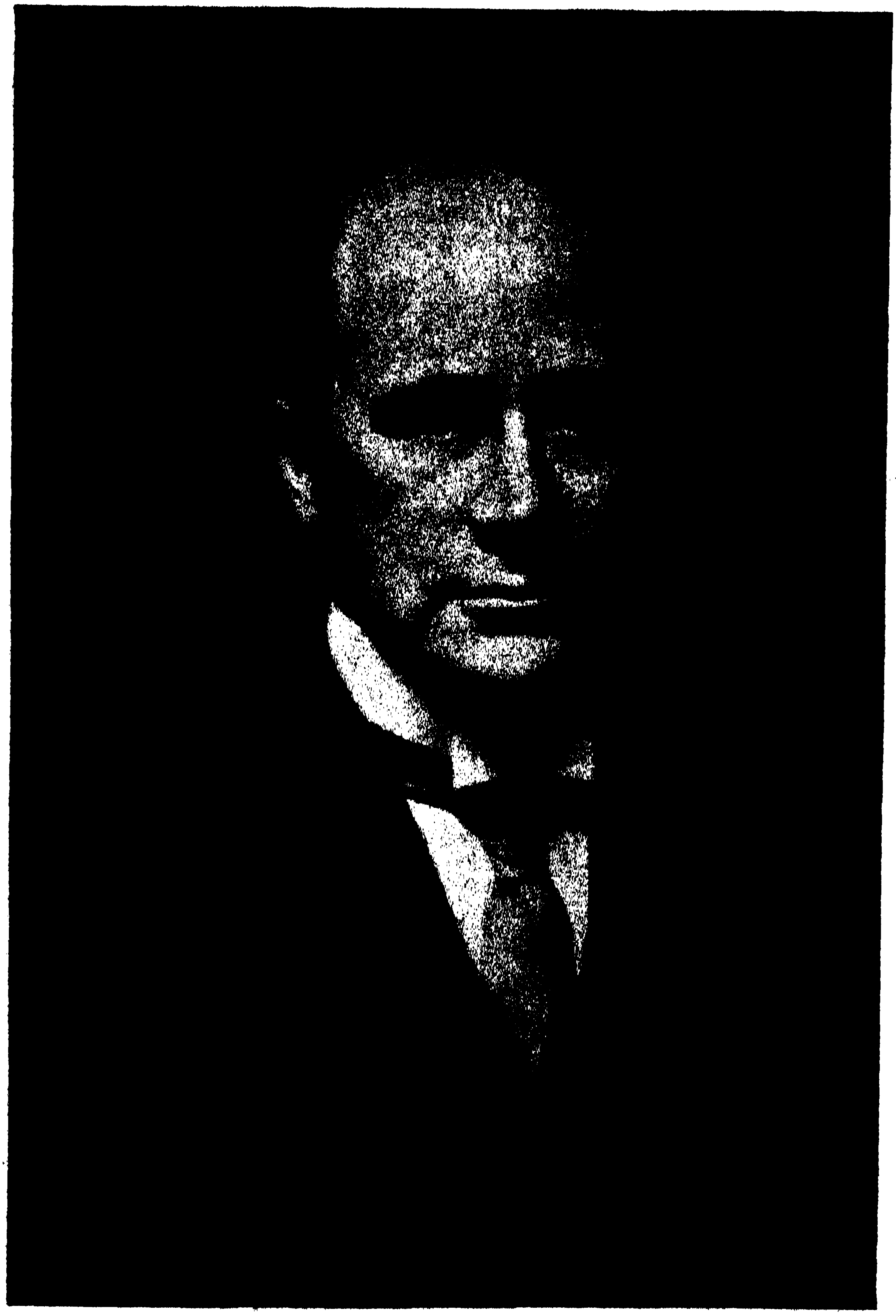
Mayo Foundation

RETIREMENT OF DR. TOWNSEND FROM THE DIRECTORSHIP OF THE NEW YORK AQUARIUM

Dr. Charles Haskins Townsend retired as director of the New York Aquarium on November 1, 1937, completing thirty-five years in that capacity. He went to this institution from the U. S. Bureau of Fisheries when the New York Zoological Society took over the management of the aquarium, which had been a city-managed institution up to that time.

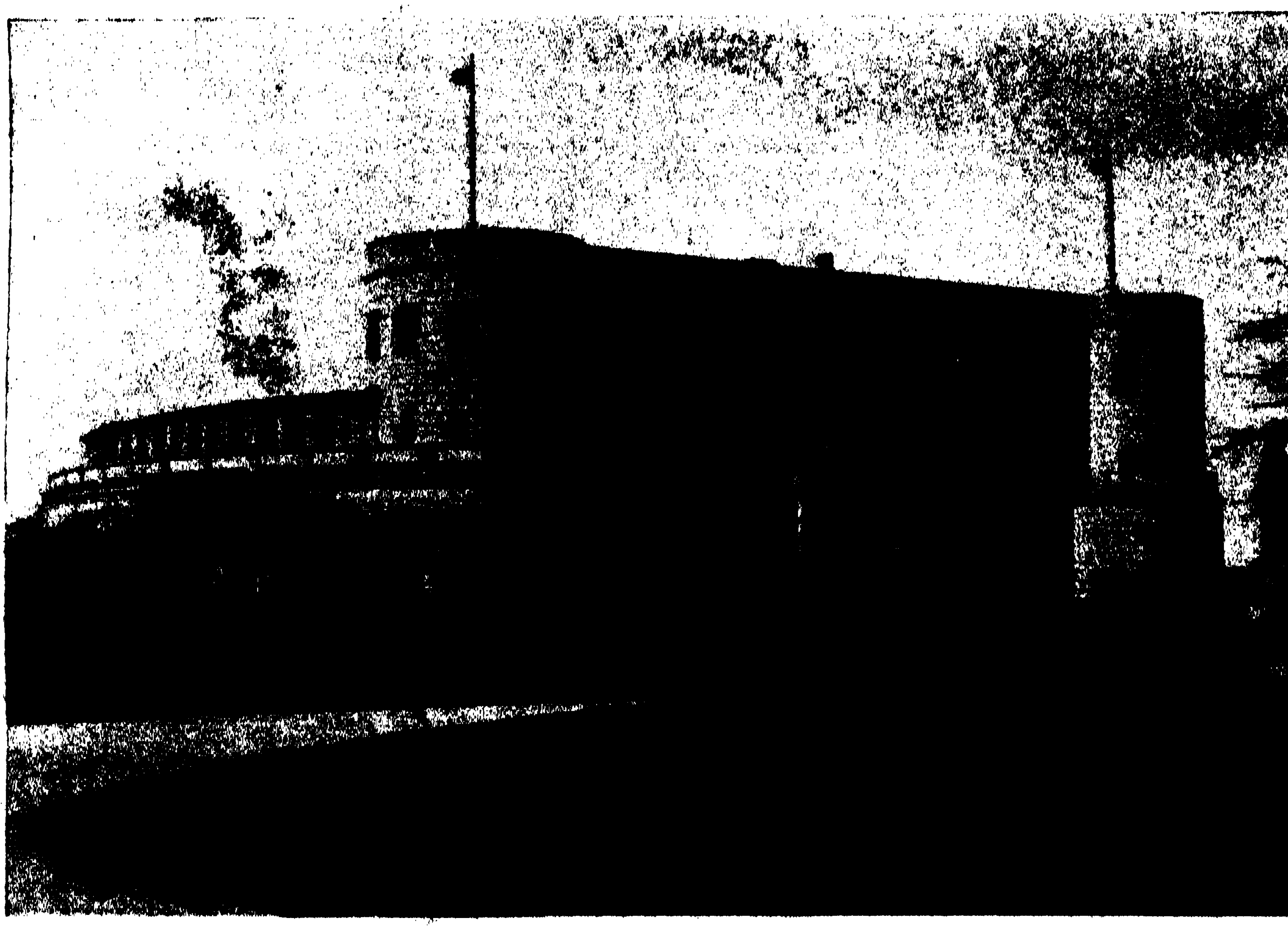
Under his guidance the aquarium has made great advances in the face of considerable obstacles. Originally the marine specimens were kept in the diluted and polluted water of New York harbor, the tanks were small, white-tiled affairs illuminated by gaslight, and the interior of the building was whitewashed. All this has been changed in these thirty-five years, in addition to which has been added a library and laboratories. The response of the public has been tremendous, and to-day the annual visitors number over two and one half million persons at an extremely low cost per visitor.

While all this has been going on, Dr. Townsend has been able to carry on his own particular researches. These in-



DR. CHARLES H. TOWNSEND
DIRECTOR OF THE NEW YORK AQUARIUM FROM 1902 TO 1937.

clude publications ranging from the migratory habits of whales to the color changes of which various fishes are capable. Since being at the aquarium, although expeditions were rather few because of obvious reasons, two trips were made to the Galapagos Islands in the interests of studies on the Galapagos tortoises, which have been threatened with extinction. Formerly Dr. Townsend spent much time in the field, having made world-wide cruises on the Bureau of Fisheries steamer *Albatross* as resident naturalist.



THE NEW YORK AQUARIUM

One of the results of this work was a thorough understanding of the Pribilof Island fur seals. His intimate knowledge of these animals caused him to be sent to The Hague when international negotiations were under way concerning the conservation of these then threatened animals. A very successful international treaty resulted therefrom and for many years this source of fur has been of great value to the persons and governments involved. He also is responsible in part for the successful commercial utilization of reindeer in Alaska.

The retirement of Dr. Townsend is really a misnomer, since it affects only his responsibility for the New York Aquarium. He will continue his studies on tortoises and whales and expects to expend most of his efforts in preparing a life-time of naturalist's notes for publication.

C. M. B.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1938

THE NATURE OF SOLUTIONS AND THEIR BEHAVIOR UNDER HIGH PRESSURES

By Dr. R. E. GIBSON

GEOPHYSICAL LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

General Principles

The study of the large variety of things which may happen when different types of matter are mixed together constitutes the science of chemistry. When two or more substances are brought together in varying proportions, it frequently happens that a mixture is obtained in which we can not by any method distinguish a small sample taken from one part of it from a sample taken from any other part. Such a homogeneous mixture is called a solution and may be solid, liquid or gas.

Let us begin by considering a simple experiment. We take a flask of 250 cc capacity with a narrow neck and put into it a quantity (30 grams) of common salt. To this we add boiled water carefully so that the combined volume of the heterogeneous mixture of salt and water is just sufficient to bring the water level to a mark placed near the top of the neck. If now the flask be stoppered and vigorously shaken the salt will dissolve, a homogeneous mixture will be formed, and it will be seen that the level of liquid in the neck of the flask has fallen considerably below its former height. During the mixing the volume of the contents of the flask diminished. I propose to show that there is more in this simple experiment than appears on the surface, and that if we understood the details of what actually went on in that flask we should hold a key to the knowledge of how this solution or any other would behave under enormous pressures and possibly have a clue to some of the things that go on in our own bodies.

This last remark raises two apparently unrelated questions whose discussion will, I think, introduce the rather technical subject which forms the main part of this article. These questions are "What do we mean when we talk about understanding a phenomenon?" and "Why should we want to be interested in the behavior of solutions under high pressures?" In the light of our answer to the first of these questions we shall consider the second.

From birth to death we encounter new experiences and new phenomena and we feel that we can "explain" these new and strange events or things when we can express them in terms of phenomena with which by long acquaintance we have become familiar. This power of the human mind to assimilate the data of experience and to transform them into instruments for understanding the new and the strange may be either one of our greatest assets or the source of a stupendous delusion. In the pursuit of science we seek *knowledge* and *under-*

standing of the external world of nature. Knowledge is acquired by exploration. To search for new phenomena, new problems and new experience we fortify our senses with apparatus of all kinds and range over the whole physical universe: we define the objects of our study so that the results may be reproduced by others and our observations then become scientific facts. For examples we do not need to go beyond this institution. With the telescopes of Mt. Wilson man reaches out into space; in search of knowledge about natural phenomena such as magnetism or volcanoes he travels over continents and oceans; with the sources of intensely concentrated energy at the Department of Terrestrial Magnetism he explores the inner regions of the atom itself; in the Division of Historical Research he seeks in the present those facts that take him in spirit far into the "dark backward and abysm of time."

Scientific understanding differs from ordinary common-sense understanding in that it is based on analyzed rather than unanalyzed experience. Knowledge of physics and chemistry has taught us that all matter consists of aggregations of molecules—the smallest individuals that may exist alone; that molecules are built up of atoms and that atoms in turn consist of particles which may be electrically charged or neutral, such as electrons, positrons, protons or neutrons. Experience has also taught us certain elementary laws or principles which govern the behavior of bodies when they find themselves in certain conditions, the laws of gravitation, of the attraction and repulsion of electrical charges being examples.

These elementary particles such as atoms, molecules and electrons, these simple laws and auxiliary concepts such as forces, energy, etc., have become the familiar ideas in terms of which the physicist and chemist explain observed phenomena. With them, together with the experience known as mathematics, they attempt to build up a mental model of nature, a model which will predict phenomena that may be checked experimentally, a model which will, in short, simulate nature herself both qualitatively and quantitatively. It must be emphasized that these fundamental concepts and logic must be formulated in terms of experience and new experience may require their modification. We have seen in the last decade how the simple laws induced from the observation of familiar bodies became inadequate when applied to electrons, protons or atoms to build up a molecular mechanics, and that a new quantum mechanics based upon the new fact of experience that these elementary entities can behave both as particles and as waves had to be developed.

During the last twenty years this understanding of nature by the synthesis of a structure from ultimate particles and simple laws has become very powerful. Knowledge led to understanding, but now understanding enhances our power of acquiring knowledge. Physical and chemical theory has made possible the choice of experiments significant for future exploration, and the insight it has given us into nature has permitted us to extend our conclusions into regions which are unknown and often inaccessible to direct investigation. It is the ambition of the theoretical physicist and chemist one day to include everything that goes on in nature, animate and inanimate, in this mental structure built up from elementary principles.

But, although she may start with a few simple materials and proceed along simple lines, nature can, and does, produce extraordinarily complicated results, and those who would imitate her have a very intricate job. Even apparently simple phenomena can be very complex in that they involve simultaneous changes in a large number of vari-

ables. We may even go so far as to say that phenomena close to our every-day experience are notoriously complex. Consequently, the theoretical worker often finds himself with a problem solved in principle but so complex that he can not solve it in practice. In such cases it is necessary to resort to simplifications which may vary from mere guessing at the answer in a roundabout way to a systematic examination of all the factors involved in the complicated phenomenon in order to estimate the relative importance of these factors and to determine which of them may safely be left out of consideration for the moment without fundamentally destroying the problem. So in the wide region between exploration on the one hand and understanding in terms of fundamental physical theory on the other there lies a domain of analysis where scientific knowledge grows by the systematic experimental study of simplified problems, where the complicated phenomena observed in nature are resolved step by step into their simplest terms. In this way we find clues to how nature works in these complicated cases, clues which enable us eventually to fit the natural phenomenon into the purely theoretical structure. Not until this has been done can we really say we understand fully a phenomenon.

Before I call attention to a complicated specific problem I should like to make one further general remark. Largely on account of the limitations of the human mind we have had to divide the study of nature into circumscribed fields which we label mathematics, physics, chemistry, astronomy, physiology, etc. The cultivation of these separate fields has appealed to different types of minds, the analytical, the exact, the descriptive, the synthetic, etc., and the various sciences grew up quite separately. Superficially they contained little in common, but as each science really consisted of the accumulation of experience about the external world we can see that a gradual reintegration of the sciences was inevitable from the start. There are many sciences but one nature, or, with apologies to St. Athanasius, the sciences are one altogether not by confusion of the substance but by the unity of nature. Exchange of knowledge on matters of technique among workers in different fields is obviously advantageous, but exchange of the quintessence of experience, namely, ideas and concepts, produces epoch-making events. The ability to grasp ideas of wide significance from one field of experience and apply them to another had characterized many of those men who have moulded the course of the progress of science.

The General Technical Problem

Considering now our second question regarding high pressures, I wish to direct attention to a part played by physics and chemistry in the attack on a large-scale problem arising from the science which is concerned with the distribution of terrestrial matter in time and space—the science of geology.

Geologists have found that those portions of the earth accessible to their investigations are made up largely of igneous rocks which are compact aggregates of crystalline minerals. These rocks differ widely in their mineral content and in the types of minerals associated together. Petrologists, those who specialize in the study of rocks, have classified the different types of rocks, examined their mineral content and studied their distribution over the earth's crust. Not content with mere description and classification but wishing to get a comprehensive picture which might gather the widely assorted facts into one consistent scheme, they have sought a mechanism for the common origin of igneous rocks. In the

hypothesis of the origin of rocks which has found greatest acceptance among scientists it is assumed that the earth was once so hot that it consisted of a liquid solution of all its constituents, that as, in the course of time, it cooled, the various rocks crystallized out, and that in the main, the course of this crystallization followed the physico-chemical laws which have been discovered by examination of the fractional crystallization of other complex solutions like natural brines or metal alloys.

To make anything of this hypothesis we have to set ourselves the following problem. *Given* a liquid mixture of a dozen or so of the messiest chemical elements, which most chemists have done their best to avoid, a mixture which can produce innumerable chemical compounds which, when they crystallize out as solids, exhibit all the more disagreeable habits known to chemistry, such as formation of solid addition compounds or solid solutions, all at a white heat much above temperatures usually employed in laboratories and under pressures to which any superlative may be prefixed. *Question.* What compounds will crystallize out from this mixture, and in what order when it cools or when its pressure is changed or both, or, in other words, how do changes of temperature, pressure and composition affect the solubility of the many different minerals in this complex liquid? Such is the simplified statement of the problem which geology posed to physics and chemistry, one of the problems which has occupied the attention of the Geophysical Laboratory for thirty years.

The problem was attacked on the principles I have outlined. By chemical and physical analysis the different variable factors were detected and then they were rigidly separated and controlled, each phase of the problem being reduced to its simplest essentials. Pressure effects were excluded and systematic studies were made at high temperatures of the solubility of different minerals, first in systems of only two components, then, when these were understood, in systems of three components, and so on. Simultaneously, the results of the laboratory researches were constantly applied to the different rock formations found in nature. I need not dwell on the success of this systematic and gradual approach to this complicated problem, as Dr. Bowen dealt fully with the high temperature phases in his admirable article last year.[1] I shall rather dwell upon that factor which, I remarked, had been for the moment excluded in the high temperature work, namely, the effect of high pressures on the solubility of minerals in silicate liquids.

When the necessity of considering the effect of high pressures was realized by petrologists, they turned to physical chemistry to see what was definitely known about the general principles governing the behavior of chemical systems under high pressure. They found extremely little, largely because chemists had never had any cause to be interested in the problem. We see, then, that the problem of rock formation threw into prominence a hiatus in physico-chemical knowledge, and so at the Geophysical Laboratory Dr. Adams made provision for attacking the problem in two ways: directly by actual observation of the behavior of silicate solutions at high temperatures and under such pressures as could be conveniently produced, and, to simplify the problem even further, by a study of the behavior of simple solutions which could be examined under very high pressures at room temperature, the complicating effects of high temperature being thus for the time eliminated. I shall confine myself entirely to the indirect at-

[1] N. L. Bowen, Sci. Monthly, 40: 487, 1935.

tack which Dr. Adams began by a series of determinations of the solubilities of salts in water and other liquids under various pressures up to 12,000 atmospheres.

Formulation of Specific Problem

The direct determination of solubilities under high pressures even at ordinary temperature, although by no means impossible, is quite difficult, but the problem may be simplified without loss of exactness by application of chemical thermodynamics, a science, developed to perfection by Willard Gibbs over sixty years ago, which gives us exact relationships between the quantities we observe when we make physico-chemical measurements. According to thermodynamics a solid, X, and a solution containing X will exist together indefinitely (*i.e.*, the solution is saturated and its composition is, by definition, the solubility of the solid) if the chemical potential of X is the same in the solid as it is in the solution. Furthermore, if the chemical potential of X is greater in the solid than it is in the solution more solid X will dissolve, whereas if the chemical potential of X is greater in the solution than in the solid, then solid X will crystallize out from the solution. The chemical potential measures the driving force of chemical changes. It is also known from thermodynamics that the change in the chemical potential of a substance produced by change of pressure is measured exactly by the volume of the substance. Thus if X has a larger volume in the solid than in the solution the chemical potential of *solid* X will be raised more by the application of pressure than will be its chemical potential in the solution. Increase of pressure will increase the solubility of X in this particular case. The problem of the effect of pressure on solubility reduces itself, therefore, to one of determining chemical potential-composition relations at atmospheric pressure and of determining the volumes of pure substances and solutions and how they change with composition and pressure. Indeed the important quantity which characterizes pressure effects in physical chemistry is the volume. I shall, therefore, be able to limit my discussion of the general effects of pressure to volumes and volume changes, reminding you that any regularities or generalizations that we are able to make about volumes may, by combination with quantities all of which are measurable at atmospheric pressure, be applied directly to the influence of high pressure on such complex phenomena as solubility.

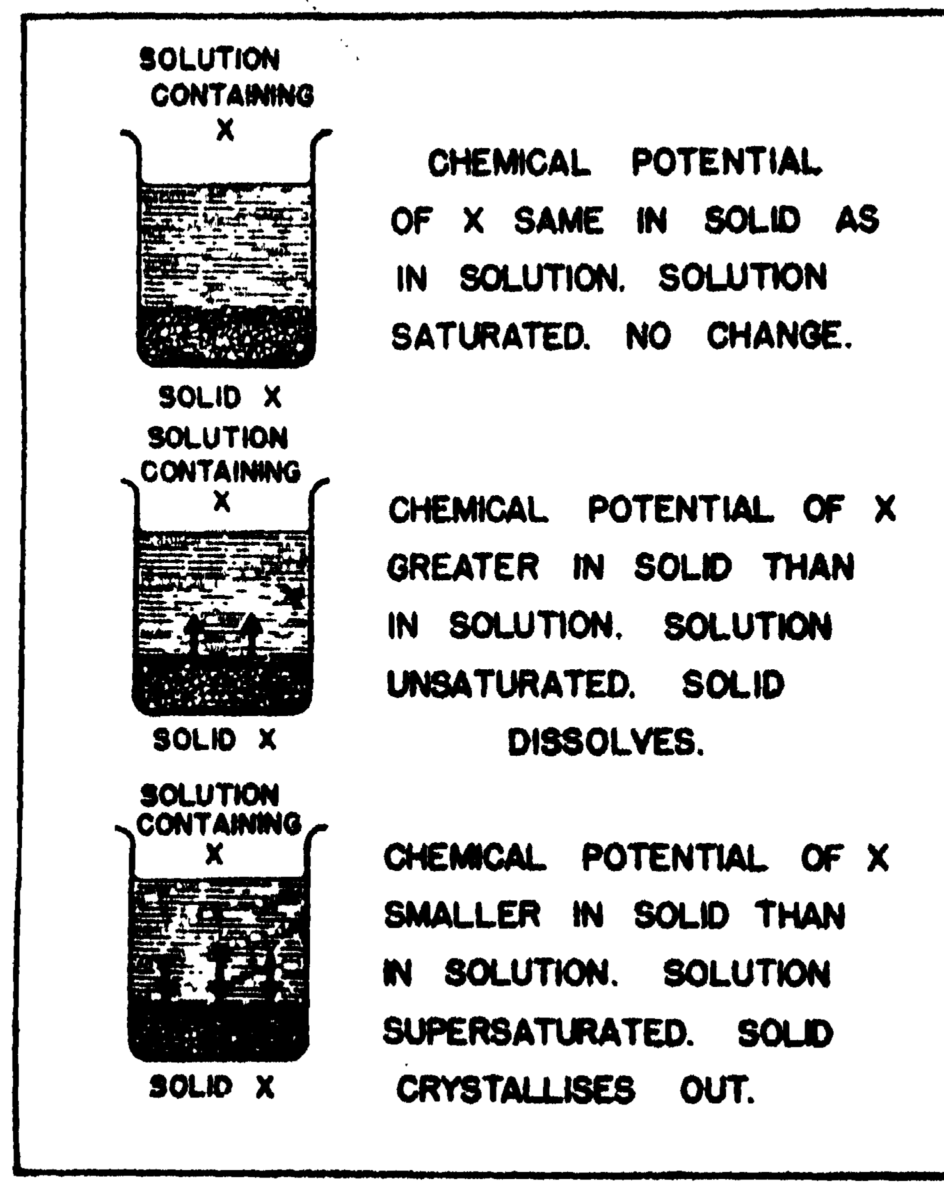


Fig. 1. Illustration of the way in which the chemical potential of a solid substance determines whether it will dissolve in or separate from a solution. The fact that the change in the chemical potential under pressure is determined exactly by the specific volumes of the substance in the solid state and in the solution is used in simplifying the study of solubilities under high pressure.

During the last few years at the Geophysical Laboratory we have made systematic observations on a large number of solutions of substances in water and in

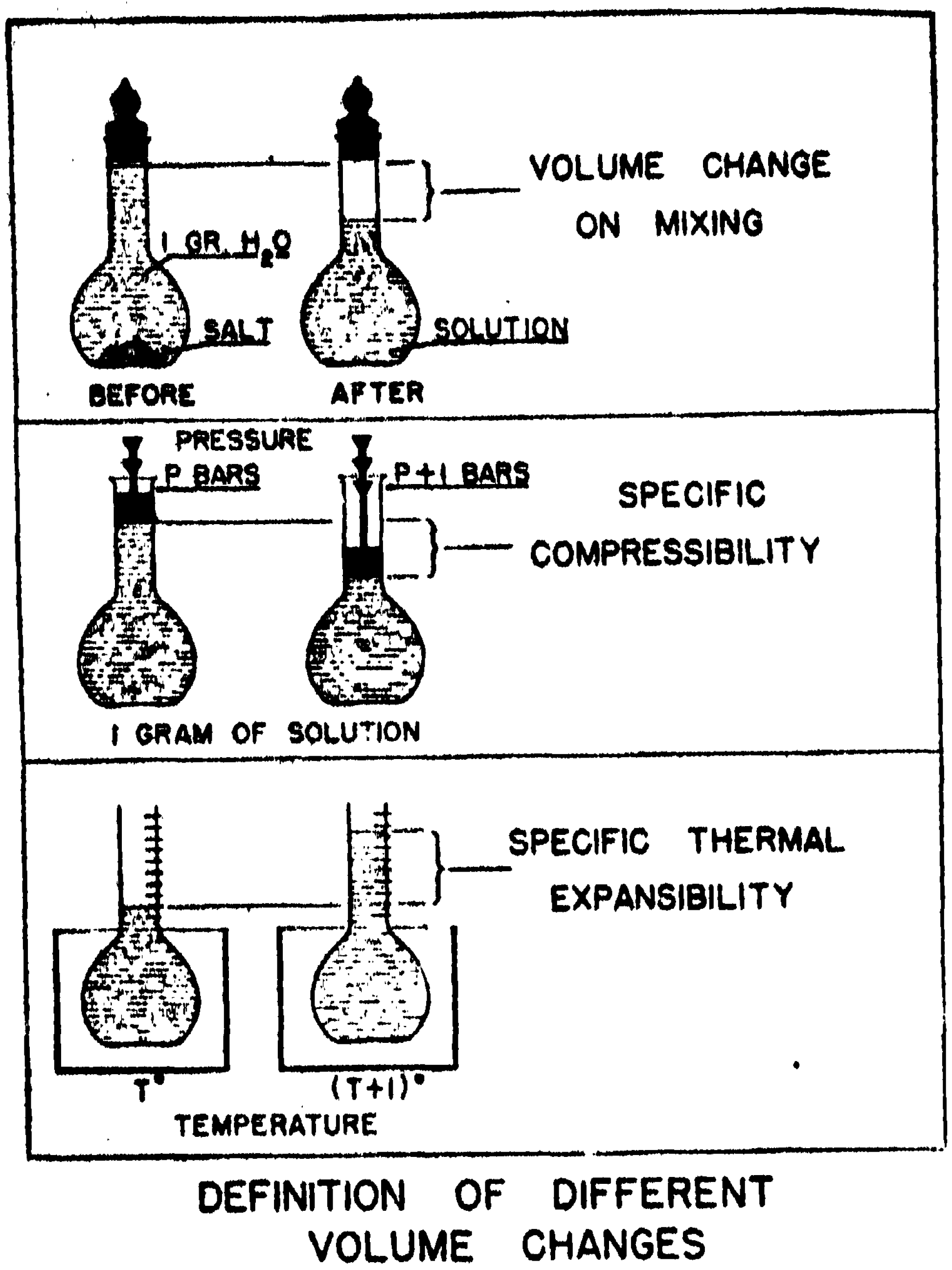


FIG. 2. DIAGRAMMATIC ILLUSTRATION OF THE MEANING OF CERTAIN TECHNICAL TERMS EMPLOYED IN THIS PAPER.

solvents like water, such as glycol and methyl alcohol. These solvents were chosen because of their high solvent powers and because the nature of solution in these solvents, especially those in water, has already been extensively investigated. For these solutions we have measured: (a) The volume changes which take place when the components are mixed in different proportions at constant temperature and pressure. From such results we can calculate by well-known methods the partial or thermodynamic volumes of the components in the solutions, these being the quantities which determine changes with pressure in the chemical potential of the substances in solution. (b) The volume changes when solutions of constant composition are subjected to definite pressure changes at constant temperature. These are called the compressions and the change in volume per gram of solution per bar rise of pressure is called the *specific compressibility*, the bar being the unit of pressure (approximately 1 atmosphere). (c) The volume changes when solutions of constant composition are subjected to changes in temperature at constant pressure. These changes are called the thermal expansions and the expansion per gram of solution per degree is called the *specific thermal expansibility*. You will see that there are three ways in which we may change the volume of a solution: we may alter the pressure, the temperature or the composition. We have studied all three.

Experimental Methods

Let me say a word or two about experimental methods. The changes in volume which take place when two substances are mixed in varying proportions to form a solution are calculated from measurements of the volumes occupied by given weights of the solution, the pure solvent and the pure solute, the general name given to the dissolved substance. These are measured by means of a pycnometer or vessel of precisely determined capacity

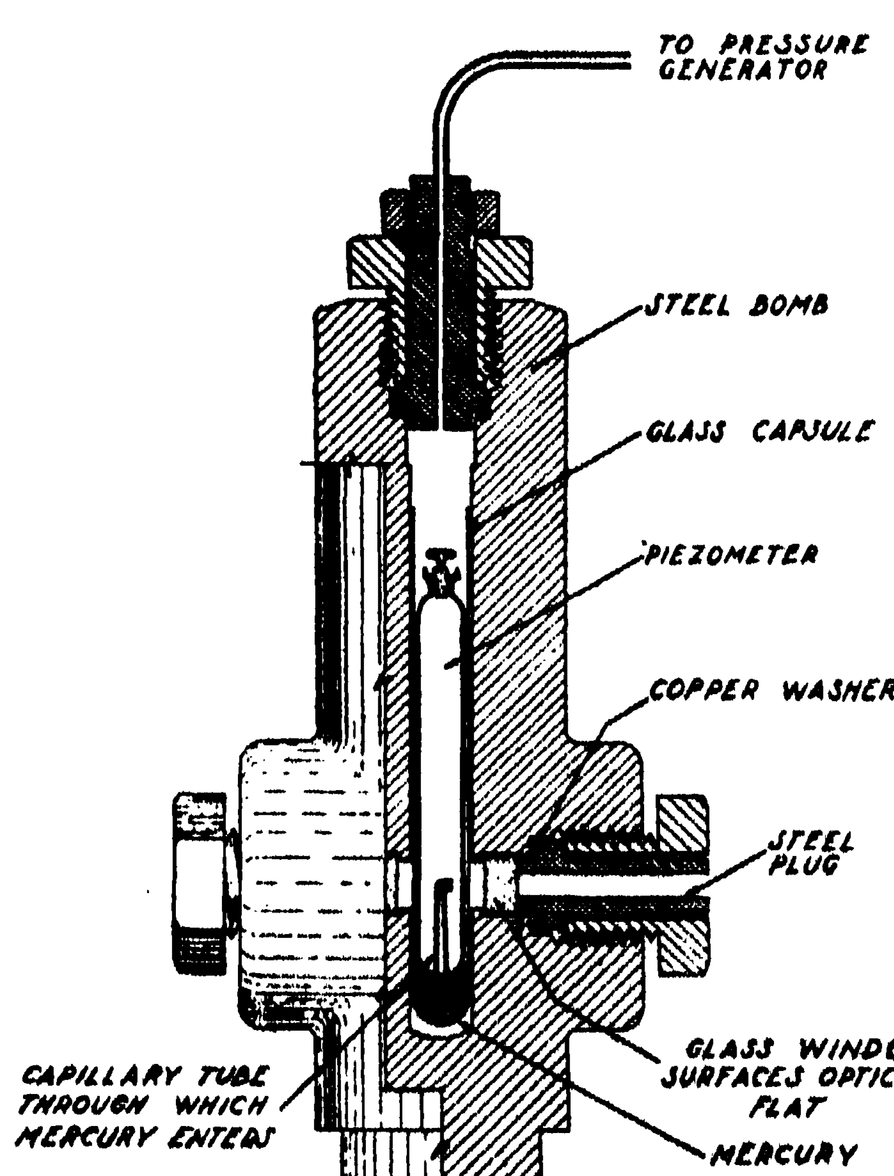


FIG. 3. DIAGRAMMATIC SKETCH OF STEEL BOMB FOR VISUAL OBSERVATION OF CHANGES UNDER HIGH PRESSURES.

whose contents we may weigh very exactly. While the pycnometer is being levelled its temperature is held constant to within two thousandths of a degree from a known value in a thermostat. To find out how much solutions expand when their temperatures are raised we used a *dilatometer*. This is a glass bulb attached to a very narrow capillary tube. The small expansion is measured by the rise in level of the liquid in a capillary tube whose bore has been carefully calibrated. Suitable corrections for the expansion of the glass must be made.

Our latest apparatus for measuring the volume changes produced by changes of pressure (compressions) consists of a heavy walled steel cylinder into which oil may be forced whereby a high pressure is generated. The liquid under investigation is contained in the piezometer—a small glass or quartz tube fitted with a reentrant tube open at the bottom. The outlet of the reentrant tube dips under mercury as shown. As the pressure in the apparatus is raised the liquid in the piezometer shrinks more than the glass does; mercury therefore runs in through the reentrant tube. It falls out of the capillary and is trapped. The final setting when the appropriate pressure is reached is made by adjusting the pressure to such a valve that the mercury is just flush with the tip of the reentrant tube. This may be readily done because the bomb is furnished with two glass windows and a microscope may be focussed on the tip of the tube. From the amount of mercury trapped in the piezometer we may determine the compression of the solution to about 1 part in a thousand with this apparatus. Altogether we have examined more than two hundred and fifty solutions at pressures as high as 1,000 atmospheres.

Discussion of Behavior under High Pressure

Let us begin a discussion of the results by asking the question: Can we express the results we have obtained in regions where observation is possible in such a way that we may predict with some confidence what will happen in regions of pressure where direct observation is impossible? In the light of what I said in my introduction one will see that this is an important question from the geological view-point. Even when we do have access to direct measurements of the effect of pressure on the solubilities of minerals in molten silicates we shall still have to extrapolate the data, as it is quite safe to say that the chances of our building a pressure apparatus in which we may duplicate conditions of pressure and temperature more than a few miles down in the earth are negligible.

In 1881 Professor Tait, interested in the oceanographic work of the "Challenger" Expedition, studied the compressibility of water and sea water and expressed the way in which the volume of water varied with its pressure by the formula now written as follows:[2]

$$V = V_0 - C \ln \frac{B + P}{B} \qquad (1)$$

At the time of Tait's work there were no measurements above 500 atmospheres, but it was found a few years ago that Tait's equation expressed the best compressibility results for water up to 10,000 atmospheres pressure with an error of less than 1 per cent. Furthermore, when Dr. Teller suggested that Tait's equation had a theoretical significance, we found that, with different constants, of course, it expresses equally well Bridgman's results[3] for the compressions of many non-volatile liquids at different temperatures over the pressure range from 0 to 10,000 atmospheres, his results for fifteen volatile liquids from 4,000 to 12,000 atmospheres and the compressions of

[2] V is the volume at any pressure P, V_0 is the corresponding volume when $P = 0$ and C and B are constants characteristic of water, ln stands for the natural logarithm.

[3] P. W. Bridgman, *Proc. Am. Acad. Arts Sci.*, 66: 185, 1931; 67: 1, 1932; 68: 1, 1933.

some solids over the whole pressure range. These circumstances give us considerable confidence that the equation I have just described does permit extrapolation over wide pressure ranges for pure solids and pure liquids near their melting points. It will quite probably be of use when applied to pure molten silicates.

We need not, however, stop at pure substances; we can use the same type of formula or law for solutions. In starting to tell about this extension, I must remind readers of the experiment I suggested at the beginning, to show that the volume of the solution was considerably less than the sum of the volumes of its components. This is quite a general effect, although cases are known where no volume change or even an expansion occurs. When I shook up that solution the molecules or ions of the salt became intimately dispersed among the molecules of the water, and the two different types of molecules acted on each other with strong attractive forces whose nature I shall discuss later. The result was a compression or contraction of the whole solution. The solutions I am considering here are all made by dissolving in liquids certain solids we call salts and we know that the specific volumes, the specific compressibilities and specific thermal expansibilities of these salts are all small compared with those of the liquids. We make the assumption, justified *a posteriori*, that these components do not change significantly in their properties on going into solution, but that the changes in volume, compressibility, etc., are due to the solvent reacting to the influence of the dissolved salt.

Now, when we see a solvent contracting upon the addition of a solute, the easiest hypothesis to make is that the salt is doing just what the application of an external pressure would do, namely, forcing the molecules of the solvent closer together. Indeed, over thirty years ago Tammann made the suggestion that addition of a solute to a solvent alters the properties of the solvent in the same way as the application of a given external pressure. From measurements of the compressibilities of solutions at low pressures we can calculate, on the assumption I just made, the compressibility of the solvent in the solution and, if we know how the compressibility of the *pure* solvent changes with pressure, we may immediately evaluate the pressure which corresponds to the action of the dissolved solid. I have called this pressure the *Effective Pressure* of the solution and given it the symbol P_e. The great usefulness of the effective pressure lies in the fact that we obtain a formula which expresses extremely well how the volume of a solution varies with pressure merely by taking the Tait equation for the pure solvent, substituting for the volume of the *pure solvent* its apparent volume in the solution, and substituting for the constant B the constant $(B+P_e)$.

Hence the formula[4] should do for solutions what the simple Tait formula does for pure substances. We have given this formula severe tests for a variety of solutions in water, and in all cases where data to 10,000 atmospheres are available the formula fits extremely well with no exceptions, even though P_e is determined from compressibilities below 1,000 atmospheres. It seems to fit for solutions in glycol as well as for those in water. Further examples must be studied, however, before we are completely satisfied.

To summarize we may say that considerable progress has been made on the question of extrapolation of compressibility measurements over the pressure range, thanks to the Tait equation or to

[4] In this formula $(V_1)_o$ is the apparent volume of water in the solution at atmospheric pressure, V_1 the same quantity at a pressure P, P_e is the effective pressure and C and B are the same as in equation 1.

$$V_1 = (V_1)_o - C \ln \frac{B+P+P_e}{B+P_e} \qquad (2)$$

related formulae. It fits well for pure liquids in regions where agreement would be expected from theoretical considerations and it may be readily applied through the idea of the effective pressure to solutions, where the compressibility of the solvent is the dominating factor. We may note that the higher the pressure the better do these equations represent the results. We also learn from these results that so long as no discontinuities appear the behavior of solutions under high pressures differs only in degree from their behavior under low pressures.

The effective pressure is calculated from the compression of the solution at one pressure. It is a number which tells us how compressible the solution will be at *all* pressures. I should note that for a given solvent the greater the *effective* pressure the less compressible is the solution. From its definition we see that the effective pressure should be intimately connected with the contractions taking place when the components of the solutions are mixed in different proportions. Our results show that this is the case for many solutions; indeed we may compute with considerable accuracy the volume change on mixing from the effective pressures, or conversely we may compute the effective pressures and hence the behavior of the solution under high pressures fairly precisely from measurements of these volume changes on mixing. Thus, if we know the compressibilities of the pure components at all pressures and the volume changes on mixing at atmospheric pressure we can form a good estimate of the compressibilities of the *solutions* at all pressures.

On the Nature of Solutions

As my main object in this article is to discuss the information which measurements of volume changes and especially of compressibilities give us about the nature of solutions, and conversely what we may say about the behavior of solutions under pressure, if we know something of the nature of the components and their interactions, I shall now turn to an account of our knowledge of the more intimate details of these solutions.

So far we have supposed that the dissolved salt merely exerted a compressive effect on the solvent. Let us then consider two questions: (a) How can we describe this compressive effect, measured by the effective pressure, in terms of the known forces between the ultimate particles of the solvent and the solute? (b) Is this compressive effect the only one or do other agencies play a part when we mix a solid with a liquid? If so, what are these other agencies and in particular how do they influence the way in which the solution will behave when we put it under high pressure?

Practically all the solutions we have examined conduct electricity and we know from well-established evidence that such solutions contain *ions* or atoms or molecules carrying free positive or negative electrical charges. These ions come from the dissolved solid. At one time it was thought necessary to explain the splitting up of the electrically neutral salt into positively and negatively charged ions when it dissolved, but we are now no longer surprised by the fact, as we know that the solids themselves are built up of ions. Thus, for instance, sodium chloride in solution gives positively charged sodium ions and negatively charged chlorine ions. To these electrically charged particles the well-established laws of electrostatics modified by the theory of probability may be applied and contributions of first magnitude have been made to our understanding of these conducting solutions from such considerations by Milner, Debye and others. We know that an electrically charged particle, like a magnet, attracts or repels other charges in the vicinity with a force that increases with the size

of the electrical charge and also with the closeness with which the charge on the particle can approach the other charges. As an ion in a solution may be looked upon as a sphere with the charge concentrated at the center, we see that the closest distance that it can approach other particles is determined by its size. The sizes of ions or their radii are well known from the extensive studies of the structures of solids and we have no reason to believe that their relative sizes are altered when these solids go into solution.

Furthermore, the molecules of which solvents like water, glycol or methyl alcohol are composed, although electrically neutral as a whole, also carry residual positive and negative charges situated at different points in the molecule. We think that it is the forces of attraction between the electrical charges on the ions and the residual charges on the solvent molecules which give rise to the effective pressure and cause the contraction on mixing. If this be so, we should expect that for equivalent solutions of different ions in a given solvent the effective pressure should increase with charge on the ions and decrease as the ionic size increases. Fig. 4 indicates that these conclusions are roughly correct. In this diagram the effective pressures of different salts in water are plotted against the ionic strength of the solution—this being a way of expressing the number of ions per 1,000 grams of water so that differences in the charges carried by the ions are compensated for. The order of increasing ionic radius is lithium, sodium, potassium, cesium for positive ions, and chlorine, bromine, iodine for negative ions. We see that the effective pressure

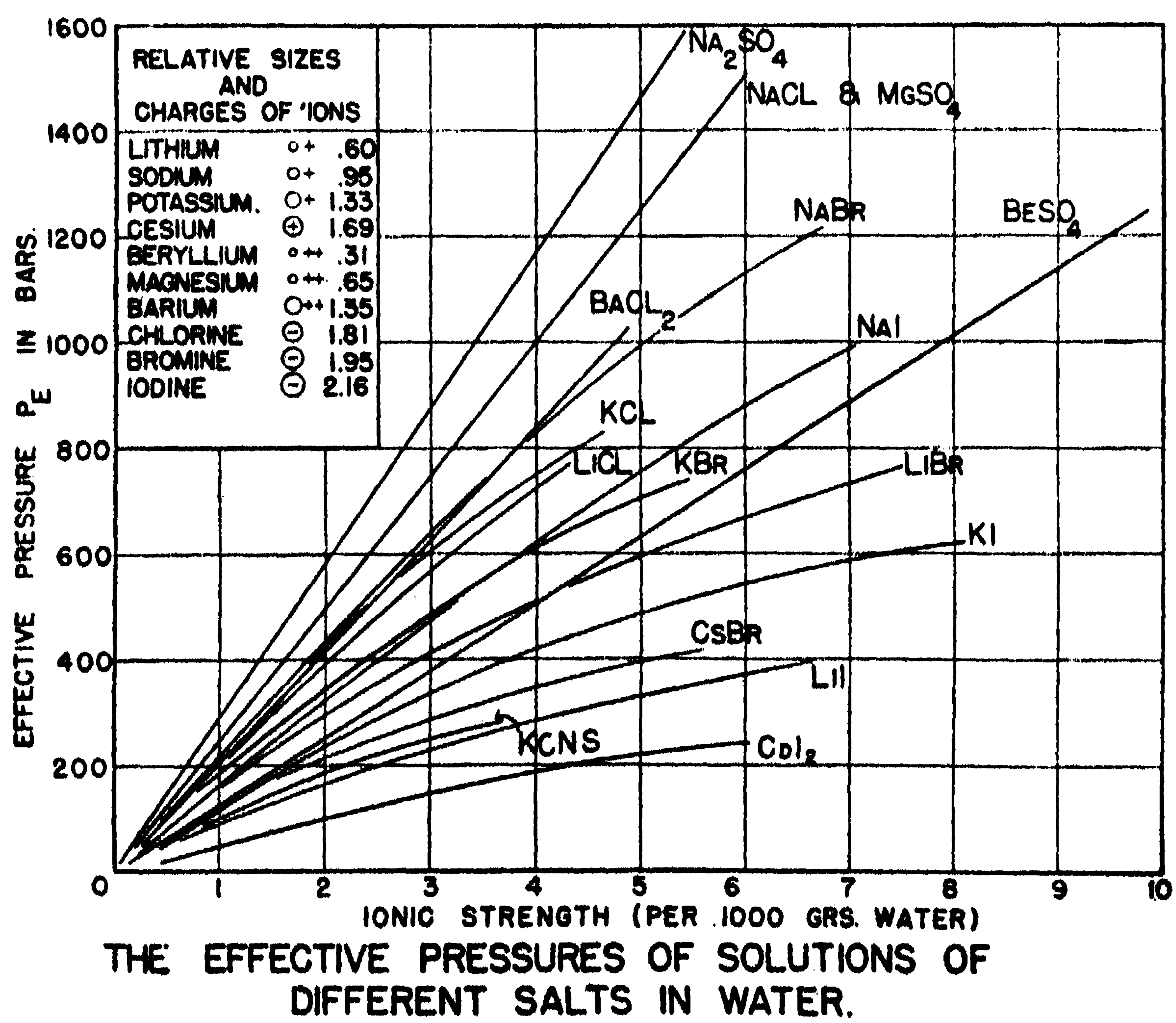


FIG. 4. GRAPHICAL SUMMARY OF SOME OF THE RESULTS OF MEASUREMENTS OF COMPRESSIBILITIES OF SOLUTIONS. THE ORDINATE EXPRESSES THE EFFECTIVE PRESSURE IN BARS (APPROXIMATELY ATMOSPHERES) AND THE ABSCISSA EXPRESSES THE CONCENTRATION OF THE SOLUTION IN COMPARABLE UNITS. THE EFFECTIVE PRESSURE MEASURES HOW COMPRESSIBLE A SOLUTION WILL BE AT ANY PRESSURE, THE GREATER THE EFFECTIVE PRESSURE THE LESS COMPRESSIBLE IS THE SOLUTION. NOTE THE WIDE VARIATION SHOWN BY THE VARIOUS SALTS.

diminishes as the ionic radius increases. In answer to our first question, therefore, we may say that the effective pressure and hence the volume change on mixing and the compressibility which determine the behavior of the solutions under high pressures depend primarily on the electric forces of attraction between the solvent and the dissolved substance. It may be added that in cases where the dissolved substance does not split up into ions but remains electrically neutral the effective pressures of the solutions are very low.

Lithium salts exhibit, however, highly exceptional behavior in water solutions which is absent in the glycol and methyl alcohol solutions, and this suggests that other agencies are also at work in aqueous solutions. The value of P_e, the effective pressure, for solutions of lithium salts in water is much too small. The lithium ion is one of the smallest ions and yet the effective pressures of lithium chloride solutions are much less than those of sodium chloride solutions. Salts of beryllium and magnesium behave in water like those of lithium. A comparison of the contraction which occurs when lithium salts dissolve in water and in glycol also reveals an abnormal behavior. All considerations lead us to expect a greater contraction on the formation of solutions in water than in glycol, but experiment shows that lithium salts produce a greater contraction in glycol than they do in water solutions. Furthermore, other lines of experiment such as the measurement of vapor pressures convince us that the forces of attraction between lithium ions and water must be very strong, but as a matter of fact lithium salts produce an exceptionally low contraction when they are mixed with water.

Examination of data we have recently obtained on the thermal expansibilities of solutions brings home to us even more strongly the fact that the hypothesis that the properties of water in a solution are those of pure water under an external pressure equal to the effective pressure does not by any means explain all that goes on in an aqueous solution. We have found that, in general, salts raise the thermal expansibility of water by an amount which is far greater than we should expect from the effective pressures and furthermore the different salts produce effects which can not be correlated by consideration of just the attractive forces their ions exert on the water. On the other hand, we find that the thermal expansibilities of the solutions of salts in glycol and methyl alcohol are very close to what we should expect from the effective pressures of the solutions. There is evidently something curious about water and we must now look more closely into the nature of this liquid.

The Internal Structure of Water

During the last decade our ideas of the nature of liquids have undergone revolutionary changes. For nearly fifty years we have had a very adequate theory of gases where the molecules are far apart compared with their size and where they are distributed at random. We have also seen in the last twenty-five years the development of an exact theory of solids where the molecules and ions are close together and arranged in perfectly definite order. We used to think of liquids merely as gases in which the molecules had come very close together, but little progress was made with this picture. It has been shown by examination of the scattering of x-rays by liquids, an experimental method, you recall, which gave us the foundations of our knowledge of solids, that molecules are not distributed randomly in liquids as they are in gases but that there is a curious kind of order. At a fixed distance around any particular molecule whose center of gravity is slowly moving there are clustered on an average a definite number of *nearest neighbors.* This gives a type of structure which

differs from the solid in that there is very little influence of any particular molecule on its *next* nearest neighbors or molecules still farther removed. This and other evidence leads us to regard a liquid as a melted solid where the definite orderly structure of the solid has been broken down but not completely.

These ideas were applied to water first by Bernal and Fowler[5] and gave a satisfactory explanation of some curious physical properties of this substance. X-ray data show that each water molecule is surrounded by 4 nearest neighbors at a certain distance, and spectroscopic data show that the water molecule itself may be regarded as a sphere with residual electrical charges at four points on the sphere which are situated at the vertices of a tetrahedron. Two of these charges are positive and two are negative. By placing these spheres in contact so that the positive poles of one touch the negative poles of another we build up a structure in which each water molecule is tetrahedrally surrounded by four others. Fig. 6 illustrates a model of what such a structure, if rigid, would look like. You will see that these forces which cause the tetrahedral arrangement also make the structure a very open one, the molecules built up in this way trap a lot of empty space. Any agency which counteracts the effects of these orienting intermolecular forces will cause a diminution in the free space and hence in the volume of the liquid as a whole, and any agency which strengthens these forces will cause the liquid to expand. If we raise the temperature of such a system we give the molecules more energy of motion and they tear away from their positions in the structure or at least occupy these positions for shorter times. This is equivalent to a distortion of the structure and produces a corresponding diminution in volume (Fig. 6, A). Thus when liquid water is heated its observed thermal expansion is the resultant of two effects: (a) the ordinary expansion which occurs because the kinetic energy of the molecules has increased and (b) a contraction due to the partial destruction of

[5] *Jour. Chem. Physics*, 1: 540, 1933.

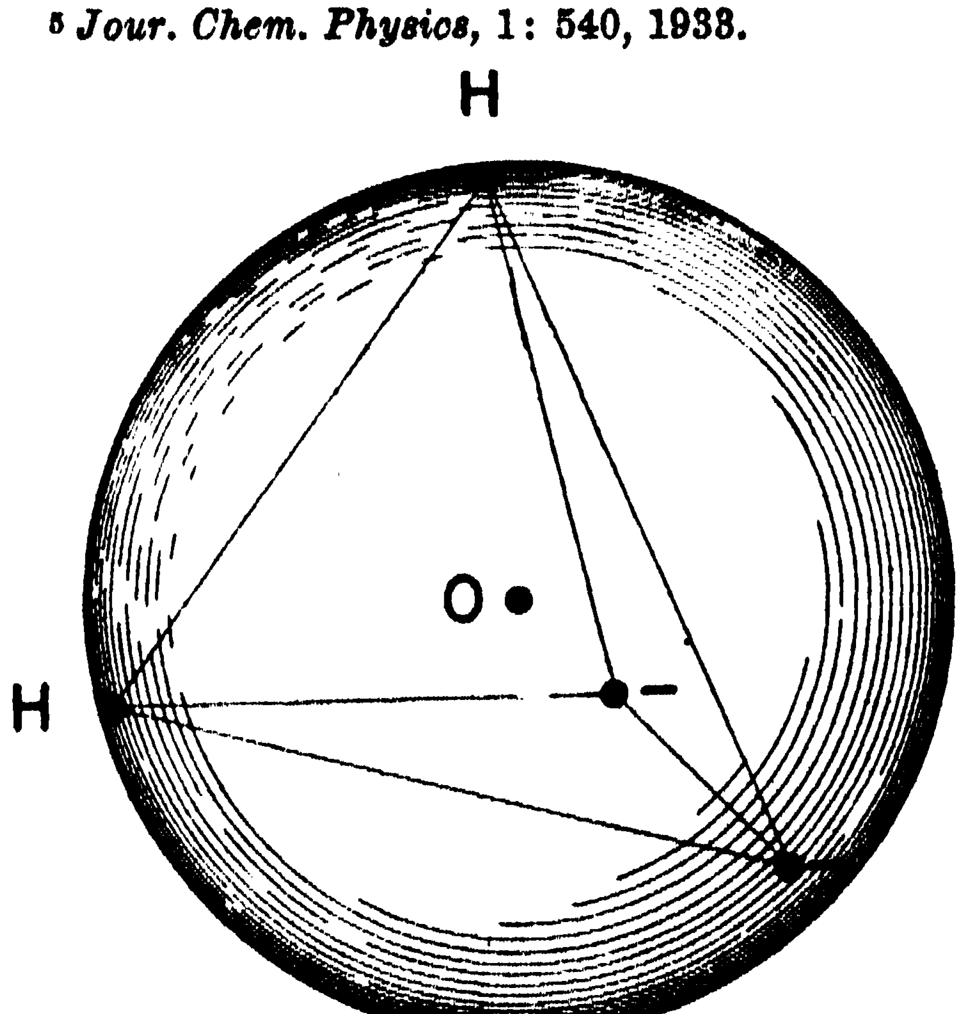


FIG. 5. SKETCH OF THE HYPOTHETICAL STRUCTURE OF THE WATER MOLECULE (AFTER BERNAL AND FOWLER). THE CENTER OF THE OXYGEN ATOM LIES AT THE CENTER OF THE SPHERE. THE TWO HYDROGENS WITH VIRTUAL POSITIVE CHARGES AND TWO VIRTUAL NEGATIVE CHARGES (–) ARE PLACED AT THE CORNERS OF AN INSCRIBED TETRAHEDRON. THE SPHERE INDICATES THAT VOLUME INTO WHICH OTHER ATOMS CAN PENETRATE ONLY WITH EXTREME DIFFICULTY.

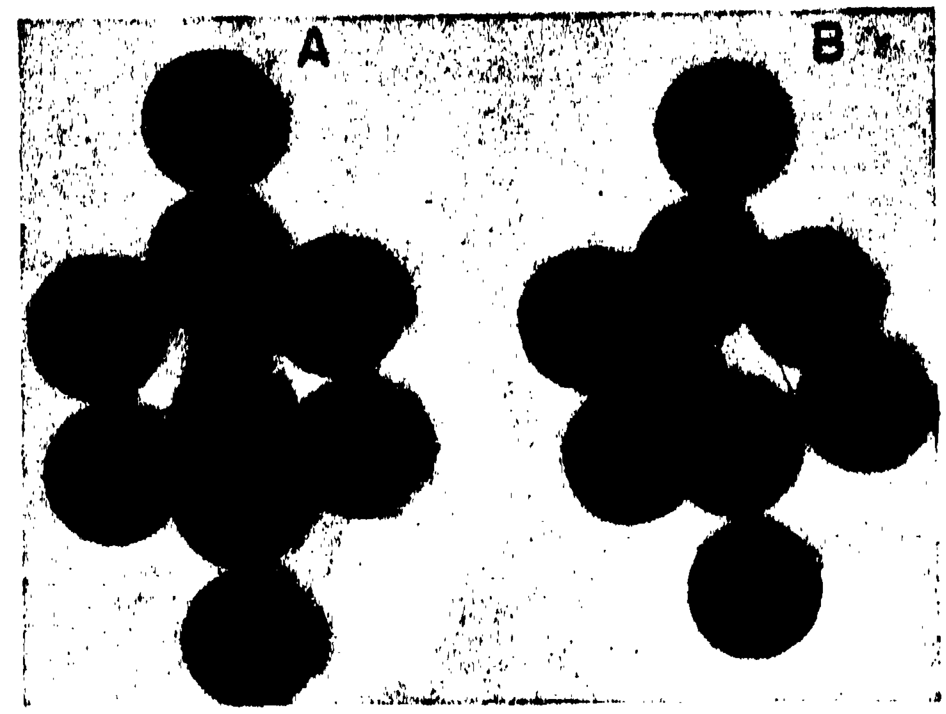


FIG. 6. IDEALIZED MODEL OF THE ARRANGEMENT OF WATER MOLECULES IN LIQUID WATER. EACH WATER MOLECULE (BALL) IS TETRAHEDRALLY SURROUNDED BY FOUR OTHER MOLECULES. STRUCTURE A IS APPROACHED IN COLD WATER. NOTE LARGE AMOUNT OF EMPTY SPACE IN STRUCTURE. WHEN THE FORCES BETWEEN MOLECULES ARE WEAKENED, A STRUCTURE RESEMBLING B (WITH LESS EMPTY SPACE) RESULTS.

the open structure I have described. This accounts for the very small thermal expansibility of water at low temperatures; at 25°, for instance, it is only one third to one quarter of what would be expected for a normal liquid. At lower temperatures, as you know, the expansion even becomes negative, the contraction due to decay of the structure being the predominant factor, and water contracts when heated between 0 and 4° Centigrade. When we apply high pressure to water we tend to crush this structure, but several considerations lead to the conclusion that this effect is very small.

Although all liquids seem to have some type of structure, that is to say, the molecules are not distributed randomly in space, it is only in water that this tetrahedral arrangement is possible. The nature of the water molecule sets water apart from other common liquids and permits a grouping together of the molecules into a structure whose volume is very much greater than that of a close-packed or random arrangement of the molecules.

The existence of a definite kind of structure or orderly arrangement of the molecules in liquid water shows us that we must modify our ideas somewhat about what happens when we dissolve a substance in water. Not only will dissolved ions attract the water molecules, but they will also have some influence on this structure. Limitations of space will not let me treat these effects in detail, but, briefly, this picture of the nature of liquid water does enable us to correlate qualitatively at least the very diverse types of volume changes which occur when different aqueous solutions are formed and when the temperature or pressure of these solutions is changed. For example, the curious behavior of solutions of lithium salts in water is accounted for. The lithium ion, being a very small one, can get close up to a water molecule and attracts the negative ends of the water very strongly. The result is that the lithium ion is surrounded by four firmly bound water molecules. This should produce a large contraction and give a high effective pressure. But we must assume that in attracting the negatively charged ends of the water molecule the lithium ion polarizes the water molecule, that is to say, it tends to pull the negative electricity towards it and repel the positive electricity to the other ends, making the electrostatic forces which hold the water molecules together stronger. This tends to strengthen the openwork structure and hence produce an increase in volume of the system as a whole. This effect is illustrated roughly by the diagram in Fig. 7. Thus the net result is that the lithium ion compresses the water less than it would have done had the structural effects been absent—we have less contraction on solution, higher compressibilities and less effective pressures. Beryllium and magnesium ions behave like lithium ions, they are relatively small and also carry two charges instead of one. On the other hand, sodium and potassium ions, which are larger than and carry the

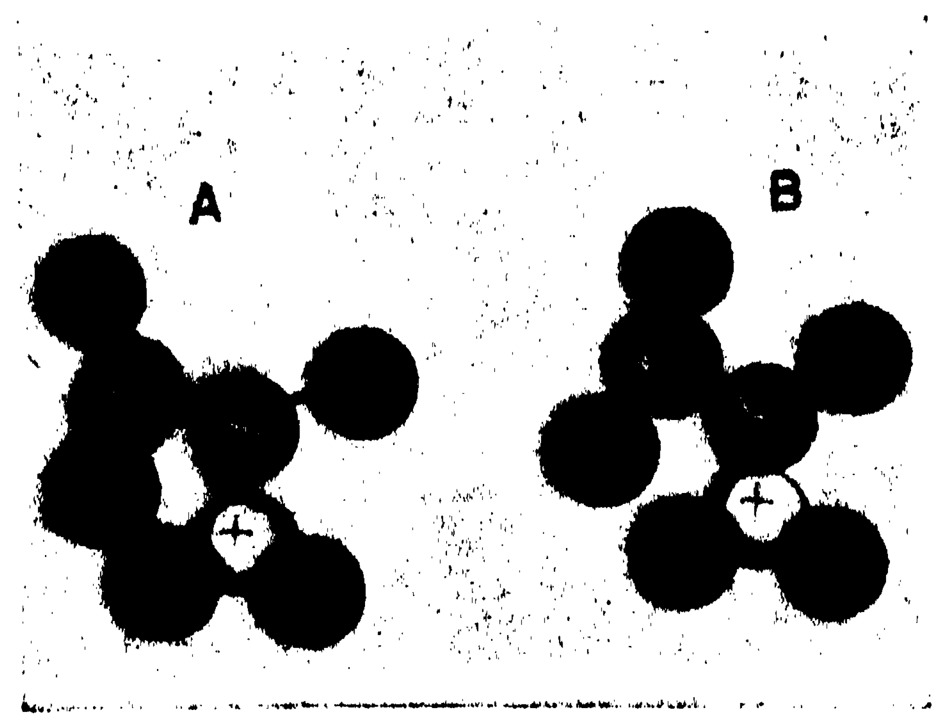


FIG. 7. ILLUSTRATION OF THE ACTION OF LITHIUM IONS (SMALL WHITE BALL) ON WATER MOLECULES (BLACK BALLS). IN MODEL A THE LITHIUM ION IS APPROACHING THE MOLECULE MARKED BY A CROSS. THE STRUCTURE OF WATER IS LIKE B, FIG. 6, IT TRAPS LESS EMPTY SPACE. WHEN THE LITHIUM ION GETS CLOSE TO THE WATER MOLECULE THE BONDS HOLDING THE MOLECULE TO ITS NEIGHBORS ARE STRENGTHENED (B), THE STRUCTURE THEN TENDS TO BECOME LIKE THAT SHOWN IN MODEL A, FIG. 6, THE MORE BULKY STRUCTURE.

same charge as the lithium ions, attract the water molecules and produce a contraction but do not polarize the water molecules to the same extent as do the lithium, calcium or magnesium ions. It has long been recognized that the sodium and potassium salts in living organisms act quite differently from calcium or magnesium salts, the effects being antagonistic, a difference which is quite mysterious.[6] We do not know enough of the details yet to draw conclusions, but it is not too much to say that these volume and compressibility measurements which are sensitive and quantitative do throw light not available from other sources on the effects of salts in the solutions which occur naturally in plants and animals.

In water and water solutions the thermal expansibilities are more strongly influenced by structural changes than are the compressibilities. For example, a change in temperature from 20° to 80° C. triples the thermal expansibility of water but has practically no effect on the compressibility. This gives us a clue to the question why the simple idea of the effective pressure is so useful quantitatively when applied to the behavior of aqueous solutions under pressure changes but is quite inadequate when applied to thermal expansions.

The Effect of the Volumes of Ions on the Properties of Solutions

The volumes of the dissolved molecules merely by their mechanical effects also seem to have an important influence on the behavior of solutions under changes of pressure and temperature and I shall close with a short account of what I imagine this effect to be and of three lines of evidence which support my speculations. The water molecule pictured in Fig. 6 is a highly reactive individual—it tries to attach itself to other molecules. In liquid water the molecules adhere to each other and the attractive forces set up an internal pressure which we may express by the quantity B in Equation 1.

If now we introduce a dissolved substance three things may happen. By their bulk the molecules or ions of the dissolved substance separate the water molecules from each other, thereby reducing the attractive forces between them. This will result in the diminution of the internal pressure of the water and a change in the structure, the open water structure will be broken down just as by a rise of temperature. There will also be forces between the dissolved ions and the water molecules giving the effects we have already discussed.

On the diagram in Fig. 8 I have plotted the apparent thermal expansions of water in different salt solutions against the effective pressure. If the effective pressure had been the only factor governing the expansibilities then all the points would have fallen on one curve. They do not, but we see that they fall on a series of curves which are characterized by the size of the negative ions, the chlorides, bromides, etc. The larger the negative ions the greater is the increase in the thermal expansibility of water they produce, in consequence of their greater effect in breaking down the water structure and minimizing the structural contractions when the water is heated.

A glance at Fig. 4 will emphasize the specific effects of the ions on the effective pressures. According to the theory of Bernal and Fowler the negative ions are so large that they are electrically inert as far as their attraction of the water molecules goes, and yet we see that in equivalent concentrations sodium chloride, bromide and iodide solutions have markedly different effective pressures. The influence of the volumes of the ions on the water gives us an explanation of the phenomenon. The total internal pressure in the solution, $(B+P_e)$, is caused by the attractive forces between

[6] R. Chambers and P. Reznikoff, *Proc. Soc. Exp. Biol. and Med.*, 22: 320–22, 1925.

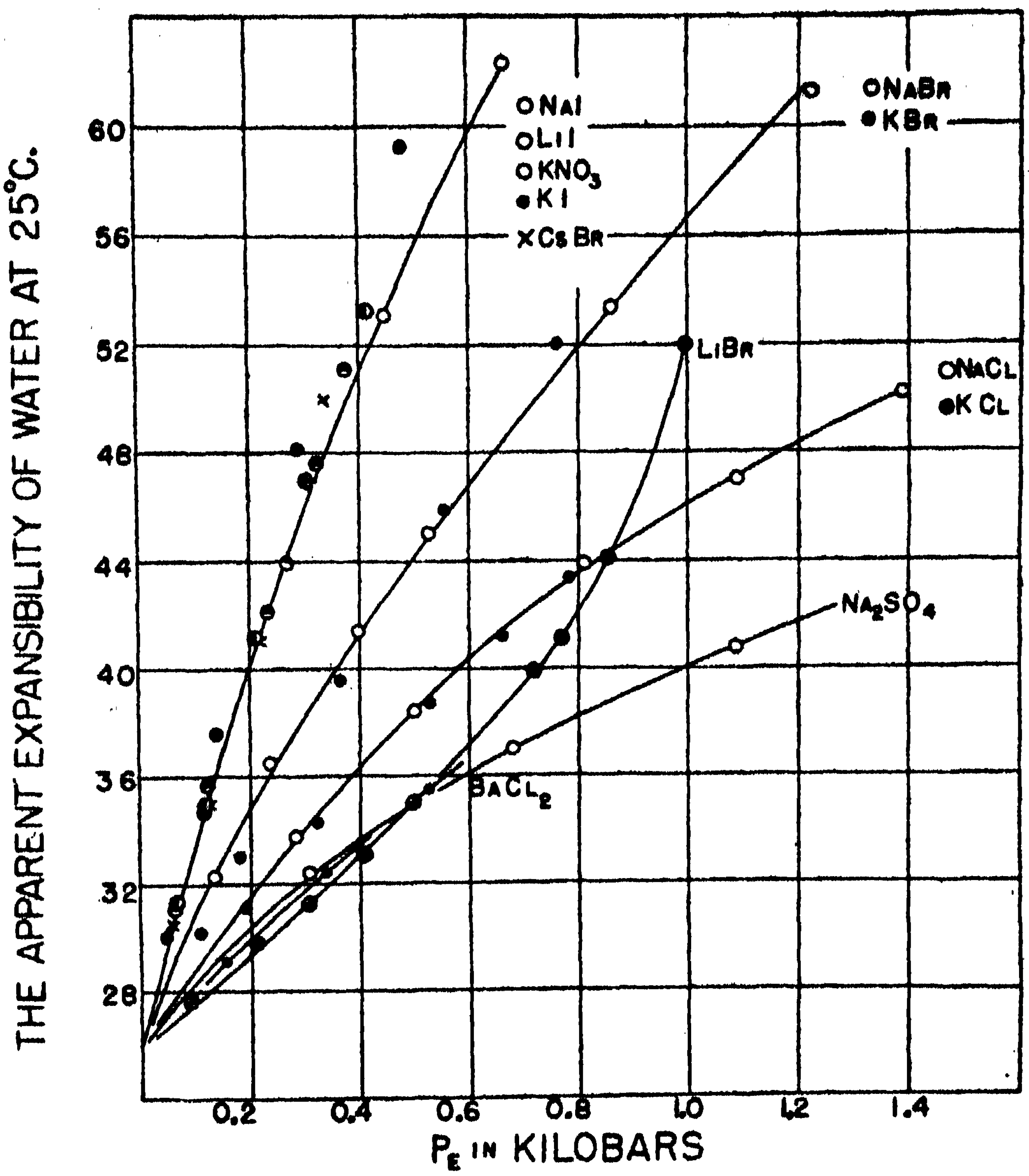


FIG. 8. GRAPHICAL SUMMARY OF RESULTS ON THE THERMAL EXPANSIONS OF SALT SOLUTIONS.

the water molecules and between the salt and water molecules. The forces between the water molecules are diminished because the average distance between them is increased by the presence of the dissolved material. The bulkier the dissolved molecules are, the greater is the decrease in the internal pressure of the water they produce. When we take this volume effect into account and compare not the effective pressures of different solutions but the total internal pressure divided by the square of the number of molecules of water per unit volume in the solution, we find that the specific effects disappear and, as will be seen in Fig. 9, the points for nine different salts fall on the same curve. Fig. 9 compared with Fig. 4 gives us considerable assurance that the pure volume effects are responsible for the specific action of the different salts. It may be noted that the exceptional behavior of the lithium salts which we have already discussed is thrown into sharp relief in this diagram.

The theory I have just described finds application in an entirely different field of the study of solutions. We know that water is present in all living matter and the solubility or dispersion of proteins in water is a phenomenon which takes us into the heart of biology. It has been found that some salts promote the dispersion of proteins and other colloids in water, others prohibit it and even cause the protein to be precipitated from colloidal solution in water. The salts which promote dispersion are all those with large negative ions such as iodides, nitrates and thiocyanates—salts, which we have seen, produce the greatest increase in the expansibility of water. If our picture of the volume effect of these ions is correct, we can see that in separating the

water molecules they free the active positive ends which otherwise were loosely attached to the negative ends of other water molecules and make them available for attachment to the active groups in the proteins, which results in the protein being brought into solution. If, on the other hand, we add a negative ion such as chloride or sulfate which is small enough or charged enough to attach itself fairly firmly to the positive poles of the water molecule we take water from the protein and it is precipitated from solution. These effects can be worked out in detail but not here. I merely wish to show that lines of reasoning, which we are forced to take if we wish to fit measurements of the effect of composition, pressure and temperature on the volumes of solutions into one consistent scheme, lead us into unexpected regions with rather striking results.

Concluding Remarks

Curiosity about the influence of high pressures on molten rocks sent us prospecting into an almost unexplored territory of physical chemistry—the effect of large changes of pressure on the solubility of salts in simple solutions. Our wanderings have led us close to the provinces of colloid- and biochemistry. At the beginning of our journey an old-timer, thermodynamics, told us that the simplest and most efficient way of exploring the influence of pressure on solubility was to study the volume changes which

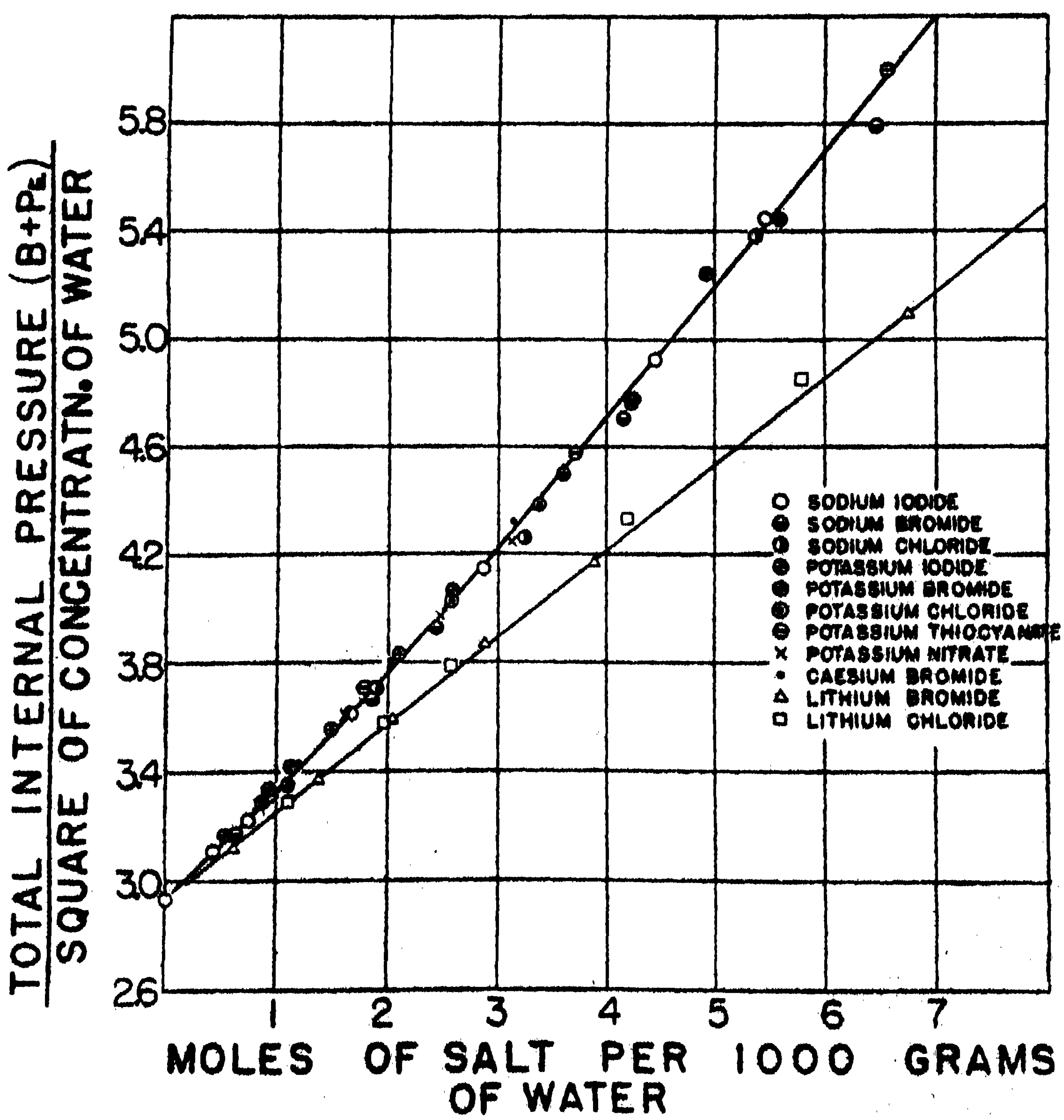


FIG 9. THIS DIAGRAM IS TO BE COMPARED WITH THAT IN FIG. 4. THE ABSCISSAE ARE THE SAME BUT AS ORDINATE THE TOTAL INTERNAL PRESSURE $(B+P_e)$ DIVIDED BY THE SQUARE OF THE MASS OF WATER PER UNIT VOLUME IS PLOTTED. FOR NINE SALTS THE POINTS FALL ON ESSENTIALLY ONE CURVE SHOWING THAT THE SPECIFIC EFFECTS OF THE DIFFERENT SALTS SO EVIDENT BY THE SPREAD OF THE LINES IN FIG. 4 HAVE BEEN ACCOUNTED FOR.

occur when a solution is made up from its components and when its pressure is varied. Our survey was facilitated by the discovery that these volume changes may be calculated over very large ranges of pressure if we know the compressibilities of the pure components at all pressures and the effective pressures set up in the solutions by the interaction of the molecules of the solvent and the dissolved substance. The Tait equation provides a way by which we may extend with confidence our observations of compressibilities at low pressures into regions of high pressures. With the help of available data on the thermal expansibilities and by comparison of solutions in different solvents we have traced the origin of the effective pressure to electrical forces between the ultimate particles of matter, to their size, and to the arrangement of these particles in space; in short, to very fundamental properties of matter.

There remains still a great deal to be done even in the study of simple solutions under pressure. Our ignorance still outruns our knowledge. Our present position may be compared to that of a man on a hillside who has cleared the neighboring woods sufficiently to see the surrounding countryside. From our little clearing in that region of physical chemistry which deals with simple solutions under pressure we can see in one direction the outline of a road to that larger province where chemists and physicists have amassed a wealth of knowledge about the ultimate constituents of matter, and the principles which govern the behavior of these particles and the methods of predicting from this knowledge the properties of matter as we ordinarily meet it. We shall have to go along this road. In the opposite direction we see through a haze that wild and rugged country we set out to explore—the high pressure chemistry of silicate solutions. A path connecting this country with us is faintly suggested by several considerations, including the following. Water consists of oxygen atoms joined by hydrogen atoms; silica consists of oxygen atoms joined by silicon atoms. Water has an abnormally low coefficient of thermal expansion over a short temperature range; silica glass has an abnormally low coefficient of thermal expansion over a large temperature range. The compressibility of silica glass increases with pressure. These facts give promise that our experience with solutions in water will help us when we enter this technically difficult region of high pressure research.

Whatever course we take in the future, one thing is certain, we must eventually blast out by simplified and controlled experiments and by judicious hypothesis a road from the domain of theoretical physics and chemistry to the jungle land of the physical chemistry of silicates under high pressures and temperatures—a road along which we may travel to and fro carrying the latest resources of fundamental understanding to subdue the complicated problems we find in nature.

GENETIC ASPECTS OF PLANT INTRODUCTION

AN APPROACH TO THE HEREDITY-ENVIRONMENT PROBLEM IN PLANTS

By A. J. BRUMAN

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SUPPOSEDLY devoid of the power of locomotion, plants have managed nevertheless, by their own means, to visit and establish themselves in places that are far distant from their native home. Their modes of travel are simple but effective: streams, ocean and air currents, the fur of animals, the clothing of man, man's implements, etc. While very effective for the purpose of self-dispersal, these methods are not selective with regard to human requirements. They are also far too slow and not very dependable for progressive mankind whose very existence is so undetachably connected with that of plants.

MAN'S DEPENDENCE UPON PLANTS

In his restless wanderings over the face of the earth man had to make sure he had with him the plants that fed, clothed and sheltered him and his live stock, that provided drugs for his medicinal needs, poison for his arrows, his firewood and the material for many articles of daily use. The first plant "introduced" by man was, probably, the seed of some favorite fruit or cereal grain, a medicinal root, a nourishing tuber or a luscious vegetable carried by a wandering primitive savage to a new place of abode.

BEGINNING OF PLANT INTRODUCTION

The beginning of more or less conscious plant introduction by man is coincident with his first agricultural effort. As his agricultural activities increased, so did the transfer of plant material from one locality to another. It was natural that the introduction of new plants should play a conspicuous rôle in the slowly unfolding process of civilization. The aggressive, adventurous spirit of the evolving human mind prompted and directed it. The exigencies of a gradually expanding agriculture demanded it.

PLANT EXPLORERS

But the settled agriculturist himself had little time or desire for travel. His new crop plants—the grains, the fruits, the grasses, the fibers, the shrubs and the flowers were brought to him mostly by wandering nomads, invading conquerors, peaceful traders, immigrants and all sorts of explorers. And so, from time immemorial this useful activity has been contributing its share of romance and adventure, pathos and tragedy, delight and enjoyment to the intricate life of the human race.

In recent years plant introduction has developed on an extensive scale. Professional agricultural explorers have visited and searched the most remote corners of the earth. As a result, many additional crop plants and new strains and varieties have enriched and advanced the agriculture of their respective countries.

PLANT INTRODUCTION IN THE UNITED STATES

The work of the United States Department of Agriculture in this regard is notable. An inventory of introduced plants started by its Division of Plant Introduction some forty years ago lists at the present time close to 120,000 individual items. Many valuable plants from among

PATRIARCHS OF A VAST INDUSTRY.

SOME OF THE ORIGINAL PARA RUBBER TREES (*Hevea braziliensis*) INTRODUCED INTO CEYLON FROM BRAZIL VIA KEW GARDENS, ENGLAND. A QUANTITY OF SEED WAS FIRST BROUGHT TO KEW, WHERE THE YOUNG PLANTS WERE RAISED. IN 1876 THESE WERE SHIPPED TO CEYLON IN SPECIALLY CONSTRUCTED WARDIAN CASES. THE ENTIRE RUBBER INDUSTRY OF THE EAST, WHICH FURNISHES 98 PER CENT. OF THE WORLD'S PRESENT SUPPLY OF RUBBER, HAD ITS ORIGIN IN THESE PLANTS.

these introductions, like numerous others brought in by various agencies and individuals, have become diffused through American agriculture. When this work started, the specialists in the various crop plants were largely occupied with the stocks already available. As the limitations of these stocks were reached, other needs became apparent. More emphasis, therefore, has been placed in recent years on expeditions organized for the special purpose of meeting these definite needs.

Among such expeditions were several, for example, that concerned themselves with exploring for disease-resistant plants. They included one for blight-resistant chestnuts to the Orient, one for wilt-resistant alfalfa to Turkestan, one for mosaic-resistant sugar-cane to New Guinea and two expeditions to South America for disease-resistant potatoes. Other special expeditions have concerned themselves with searching for drouth-resistant plants, plant material to be

WILD POTATOES IN BLOSSOM.

THE POTATO BREEDER OF TO-DAY LOOKS PRINCIPALLY TO THESE WILD RELATIVES OF THE CULTIVATED POTATO FOR THE IMPORTANT QUALITIES OF HARDINESS AND DISEASE RESISTANCE.

used in soil erosion control work, plants with insecticidal properties, and so forth.

Work in Other Countries

Extensive plant introduction has not been confined to the United States alone. It has played a prominent part in the agricultural development of such countries as Australia and the Union of South Africa.

Russia, another large agricultural country, with many problems quite similar to those in the United States, has made great strides in this type of agricultural research within the past decade. No less than sixty expeditions were engaged in during that period by Russian agricultural explorers. Directed to a large extent by the eminent Russian botanist and world traveler, N. I. Vavilov, these expeditions have concerned themselves principally with the gathering of all the species and varieties as well as all the distinguishable forms of cultivated plants. The present collection of the Institute of Plant Industry at Leningrad of the major crop plants of the world runs into hundreds of thousands. A thorough study of these varieties from a practical, taxonomic and genetic point of view is being made after their introduction. This is all part of an ambitious plan to establish and maintain a complete living collection of agricultural crop plants.

Introduction for Direct Use

Introduced plants, on the whole, may be grouped roughly into two principal classes: those brought in for direct use and those intended for the use of plant breeders and hybridizers in developing

THE NATIVE HABITAT OF WILD WHEAT.
A WILD RELATIVE OF THE WORLD'S MOST IMPORTANT CEREAL GRAIN NESTLED IN ROCK CREVICES NEAR ROSCH PINAH, PALESTINE.

new strains. One need not look very far for a list of new plants in this or in any other country. The great coffee industry of Brazil and Central America, the sugarcane industry of the West Indies, the tobacco industry of Turkey and India, tea and cacao in Ceylon, rice in South America and Southern Europe, rubber in the East Indies, maize and cotton in many lands all trace their beginning to a few unostentatious plant immigrants disseminated by the busy plant hunter.

Origin of Principal American Crops

In the United States nearly all the major crop plants have been introduced from abroad. Those found growing here by the first white settlers were very few in number. Even corn, potatoes, beans and tobacco are not, strictly speaking, indigenous crops, since they originated in South and Central America and were, apparently, brought north by migrating Indian tribes. As to our cereal grains, the great majority of our fruits and some of our principal forage grasses, as well as a number of secondary crops, these have all been introduced by white immigrants. Of more or less recent introduction are the avocado, Smyrna fig, date, soybean, lespedeza, the oriental persimmon, grain sorghums and pistache.

New Hybrids

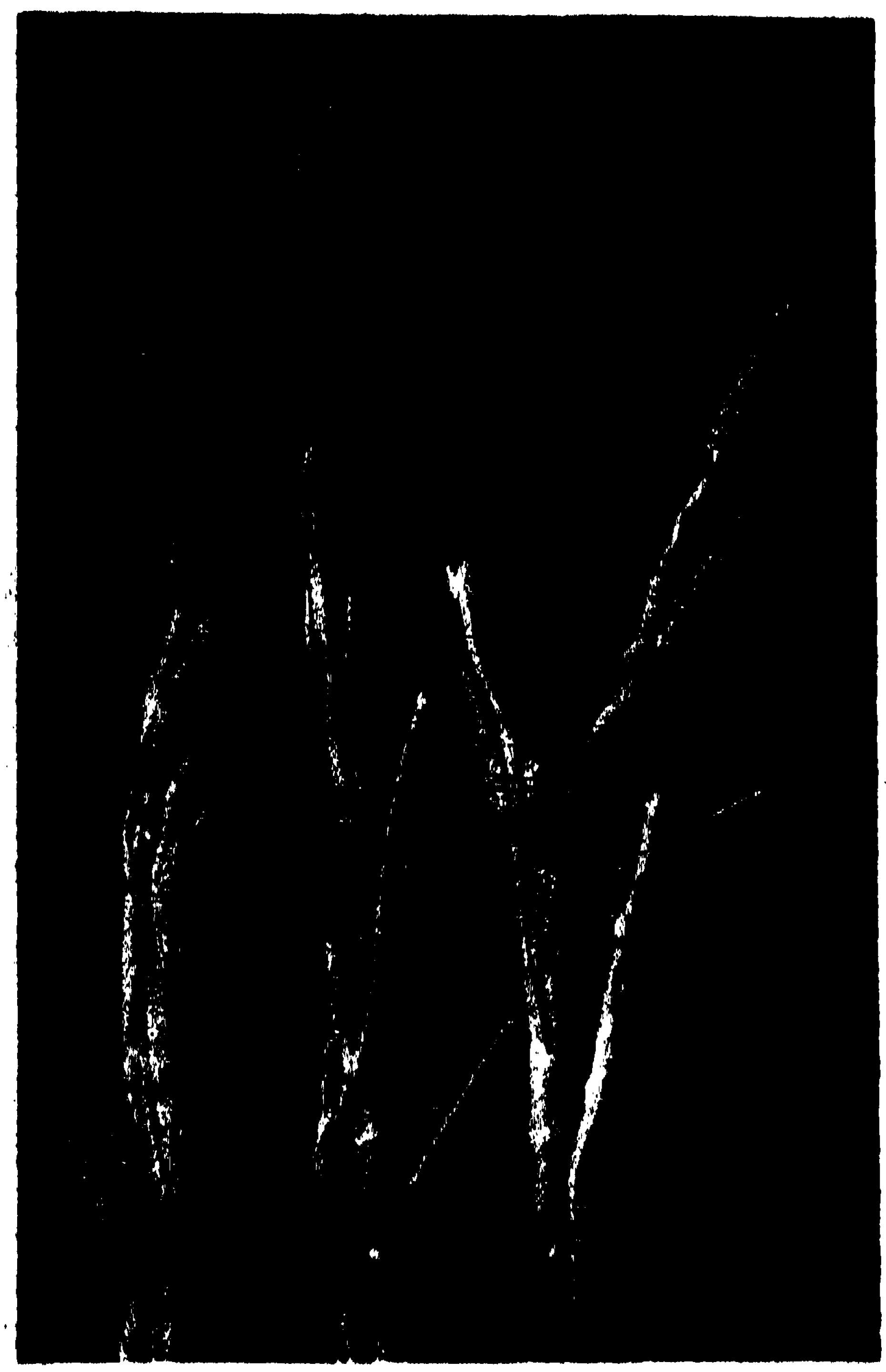
While the chance of finding new crop plants is becoming more and more rare, the sources of new varieties and strains of established crops are practically inexhaustible. New hybrids are being constantly produced both in nature and through artificial means by plant growers all over the world. Their mutual ex-

change between countries and distant localities will probably continue as long as there is any commercial or cultural intercourse between nations and individuals.

Introduction of "Raw Material" for the Hybridizer

The second type of plant introduction, as mentioned above, is for the use of various agricultural and botanical institutions, experiment stations and individual plant breeders in their hybridization and selection work. It is the plantsman's natural instinct to strive for the constant improvement of the material with which he is working. The individual or amateur

A NEW PLANT (CENTER)
RESULTING FROM A CROSS BETWEEN CULTIVATED WHEAT, TRITICUM (LEFT) AND COUCH GRASS, AGROPYRUM (RIGHT).

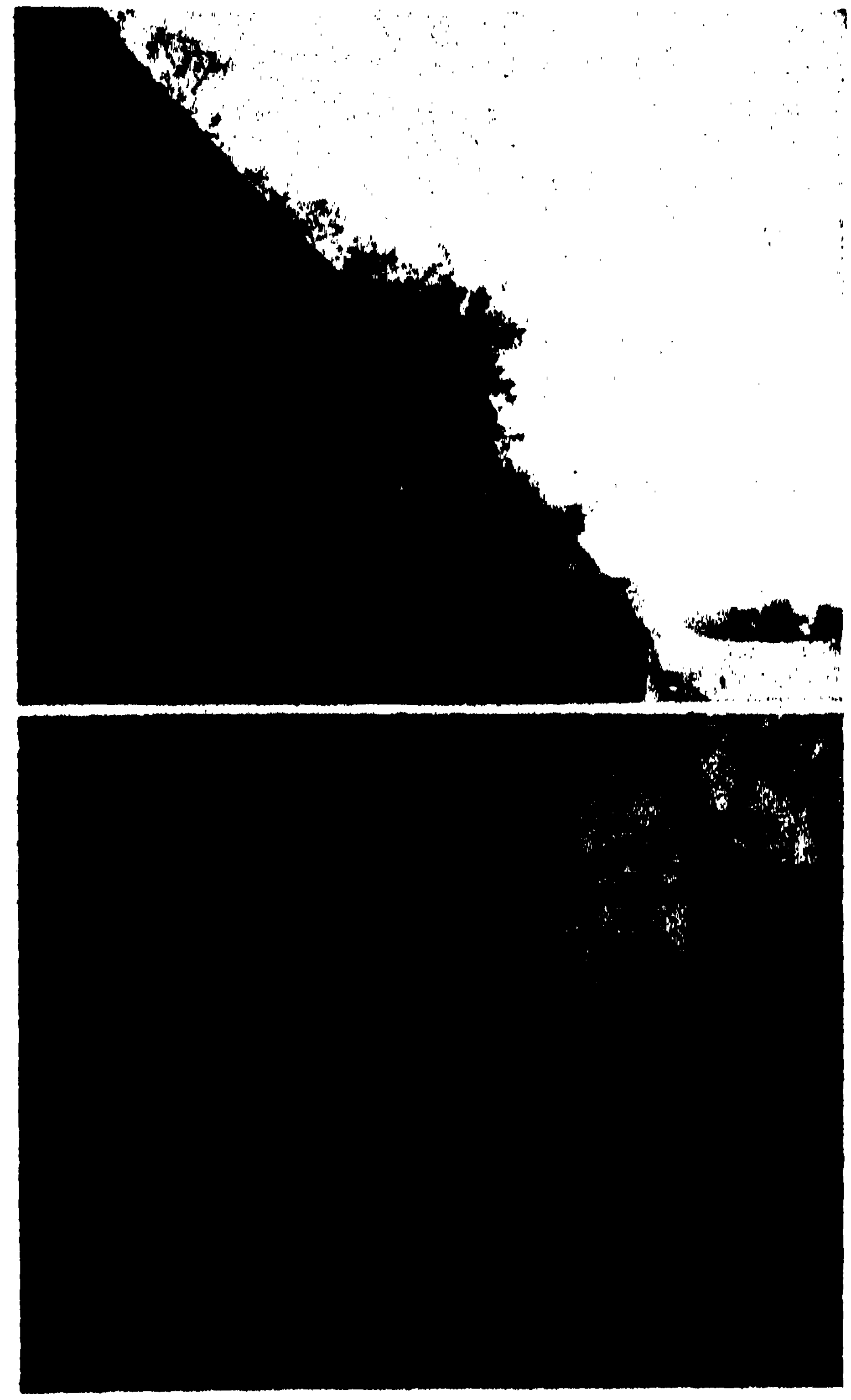


AN INTERGENERIC HYBRID
BETWEEN CULTIVATED CORN AND ITS CLOSEST WILD RELATIVE—THE TEOSINTE OF SOUTHERN MEXICO AND GUATEMALA.

plant breeder, of whom there are dozens in every locality, may be aiming towards an ideal to suit his own fancy or desire. The commercial and government geneticist, on the other hand, like the manufacturer of inanimate objects, is guided entirely by public demand or current necessity.

In addition to crossing different strains and varieties, the geneticist is now attempting more and more so-called wide crosses between plants of different genera as well as of different species. One such intergeneric cross between cultivated wheat and couch grass (Triticum × Agropyrum) is of considerable practical interest. If it does not eventually furnish the hard-working yet leisure-loving agriculturist with a form of perennial wheat, it appears at least to give definite promise of adding some valuable new forage crops to those now in cultivation. Cultivated maize (Zea) has been crossed with gamagrass (Tripsacum) and with teosinte (Euchlena). The resulting hybrids are of considerable theoretical interest. In sugar-cane breeding the use of wild relatives both within the genus Saccharum and those belonging to related genera, such as Sorghum, is being practiced extensively. As the scope of the geneticist expands in the direction of interspecific and intergeneric hybridization, the plant introducer must likewise broaden his objectives to include the search for all related genera and species of our cultivated crops in many parts of the world. The possibilities in this line of plant exploration and genetic research are fascinating to contemplate.

Frequently old varieties cease to satisfy the shifting agricultural and industrial demands. For example, a certain new type of cotton may be required for newly arising industrial uses or the rapidly developed practice of distant shipping of fruits and vegetables may have created a demand for certain types that will pack and ship well. Or styles in eating may change. A vitamin-conscious public consumes enormous quantities of fruits and vegetables and dictates not only what their vitamin content should be but not infrequently also their size, shape, color, flavor and appearance.



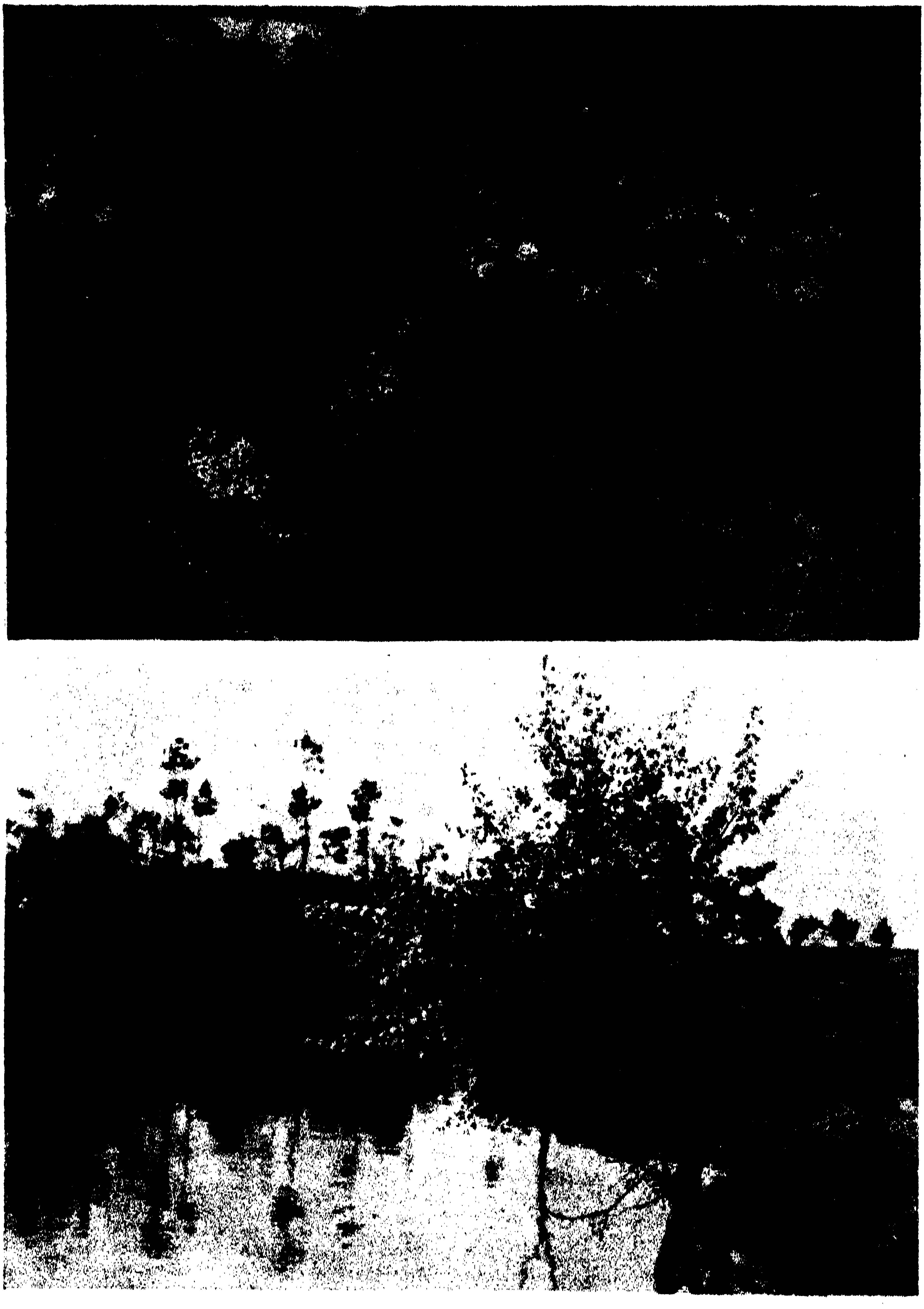
STRIKING CONTRAST

BETWEEN PLANTS OF THE SAME SPECIES IN DIFFERENT ENVIRONMENTS. WILD PEACH (*Amygdalus davidiana*), ABOVE, ON A DRY STONE WALL, IN CHINA; BELOW, IN A CALIFORNIA TEST ORCHARD.

Replacement of Old Varieties

Furthermore, some old varieties appear to "run out" for one reason or another. In the majority of cases this is due to disease or to some inherent weakness which has, perhaps, remained unnoticed until changed field practices have greatly intensified its effect on yield.

The replacement of an old established



ENVIRONMENTAL RESPONSE.

WILD PEAR (*Pyrus calleryana*) GROWING IN DIFFERENT SURROUNDINGS. BOTH PICTURES WERE TAKEN IN CHINA.

variety is not an easy matter. Rarely can it be replaced completely by an introduced one from another region. For the fact that a variety has become well established in a given locality is not a mere accident. As a rule it is due to a successful combination of important genetic factors whose expression is properly moulded into the desired form by the existing combination of external condtions which make up the local environment.

Complexities of Plant Breeding

At times two local varieties may produce the desired hybrid, but frequently new parental stock containing the sought-for genetic factors must be brought in from the outside. Here the potentialities as well as the complexities of plant introduction are truly limitless. There are numerous localities and a great wealth of material from which to choose. In hybridizing plants from the same locality multitudinous possible combinations of genetic factors may create an endless array of potentialities. But when plants from two diverse regions are to be crossed, the problem becomes much more complex, for genetic factors are not the fixed, unchangeable units with but a single, definite expression that one might suppose.

Importance of Environment

Geneticists now agree that many complex forces enter into the final expression of genetic factors. Not the least of these forces is that combination of external conditions called environment, about which, to paraphrase Mark Twain's expression regarding the weather, so much is said and little is done.

In plant introduction, which is so closely tied up with the science of genetics, environment is one of the major problems to be dealt with and can hardly be ignored. The very act of moving a plant from one environment into another immediately sets to work an array of forces which may so affect the expression of its inherent genetic factors as to bring about results that are entirely unanticipated.

ARTIFICIAL MODIFICATION OF ENVIRONMENT

UNDER LABORATORY CONDITIONS DURING GROWTH STUDIES OF INTRODUCED SOUTH AMERICAN POTATOES.

Hidden Characters

Altogether new qualities as well as faults may be uncovered through the unmasking of hitherto hidden genes under

EFFECT OF DAY LENGTH ON MATURITY.
RED CLOVER GROWN UNDER ARTIFICIALLY PRODUCED CONDITIONS OF A SHORT AND A LONG DAY. IN THIS TYPE OF PLANT THE LONG DAY FAVORS EARLY BLOSSOMING AND MATURITY.

the influence of a new environment. The expression of other desirable or undesirable genes may be equally suppressed through the lack of some one or more external conditions necessary for that expression.

Those engaged in plant introduction have long been aware of these phenomena. They can point to the navel orange, a Brazilian immigrant, now one of the mainstays of the citrus industry in California. It was originally intended for introduction into Florida but made no headway there. In fact, it does better in California than in its native home in Brazil. A case of domestic introduction is the new Katahdin potato. Bred in Maine and tried in many parts of the United States, it found its most congenial home in Michigan and in the Pacific Northwest. Two California pines, *Pinus coulteri* and *P. radiata,* of secondary importance in their native home, are now among the foremost timber trees of Australia. The American cactus, brought into Australia as a curiosity, has found its new home so much to its liking that it has literally overrun that continent and has become a serious agricultural pest there.

Climatic Analogy

The peculiar and frequently unexpected behavior of plants in new surroundings has been the basis of extensive studies in plant ecology and in plant geography. Much stress has also been laid on the comparison between climates of different parts of the world.

But climatic analogy can only be partially depended upon in plant introduction. On the one hand, there are many instances of plants that are very cosmopolitan in behavior. Vegetable and flower seeds from certain countries, for example, are exported to all parts of the world and appear to be doing equally well wherever they are grown. While in some cases the reimportation of fresh seed stock may be required every few years or even yearly, in other cases the introduced plant becomes so thoroughly

established as to furnish its own propagating material.

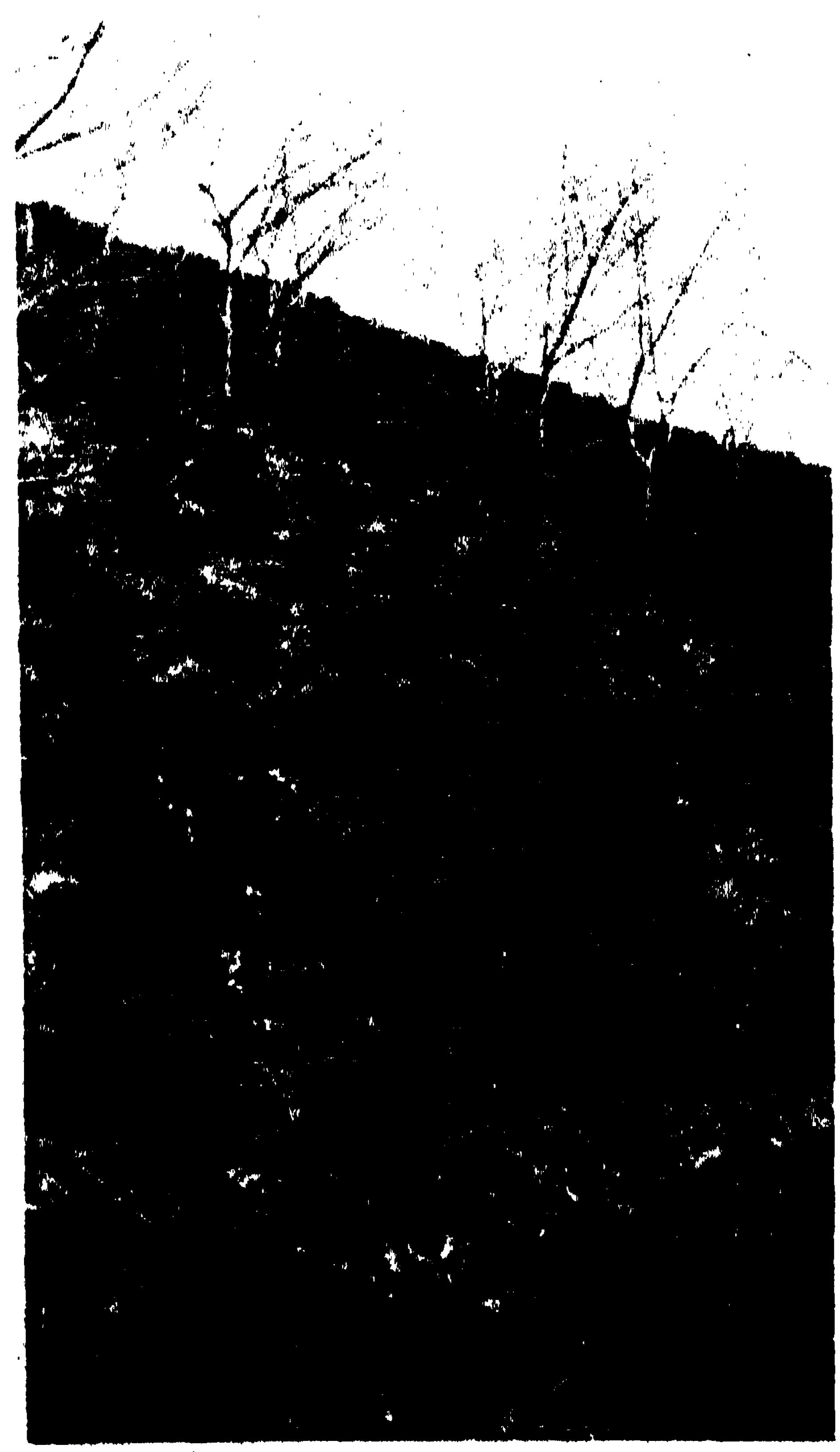
Difficulty of Accounting for Environment

Moreover, it is not easy to take into account all the conditions surrounding the growth and the development of plants. Nor is it easy to forecast the various responses of the plant organism to a complete or even to a partial change in environment. For who can tell beforehand what hidden genetic factors lie dormant within the cell nucleus that only await the proper set-up of external conditions to express themselves in perceptible form? Of these external conditions we have, among other things, temperature with its daily and seasonal fluctuations, length of day, length of growing season, precipitation and atmospheric pressure, the soil in endless variety of physical composition and organic and inorganic content, the presence or absence of competing or preying organisms and the many possible combinations of all these. It is no wonder that both the average geneticist and plant introducer are willing to let environment more or less take care of itself. They have enough to do working with genetic factors under any particular environmental set-up.

Manipulation of Environment

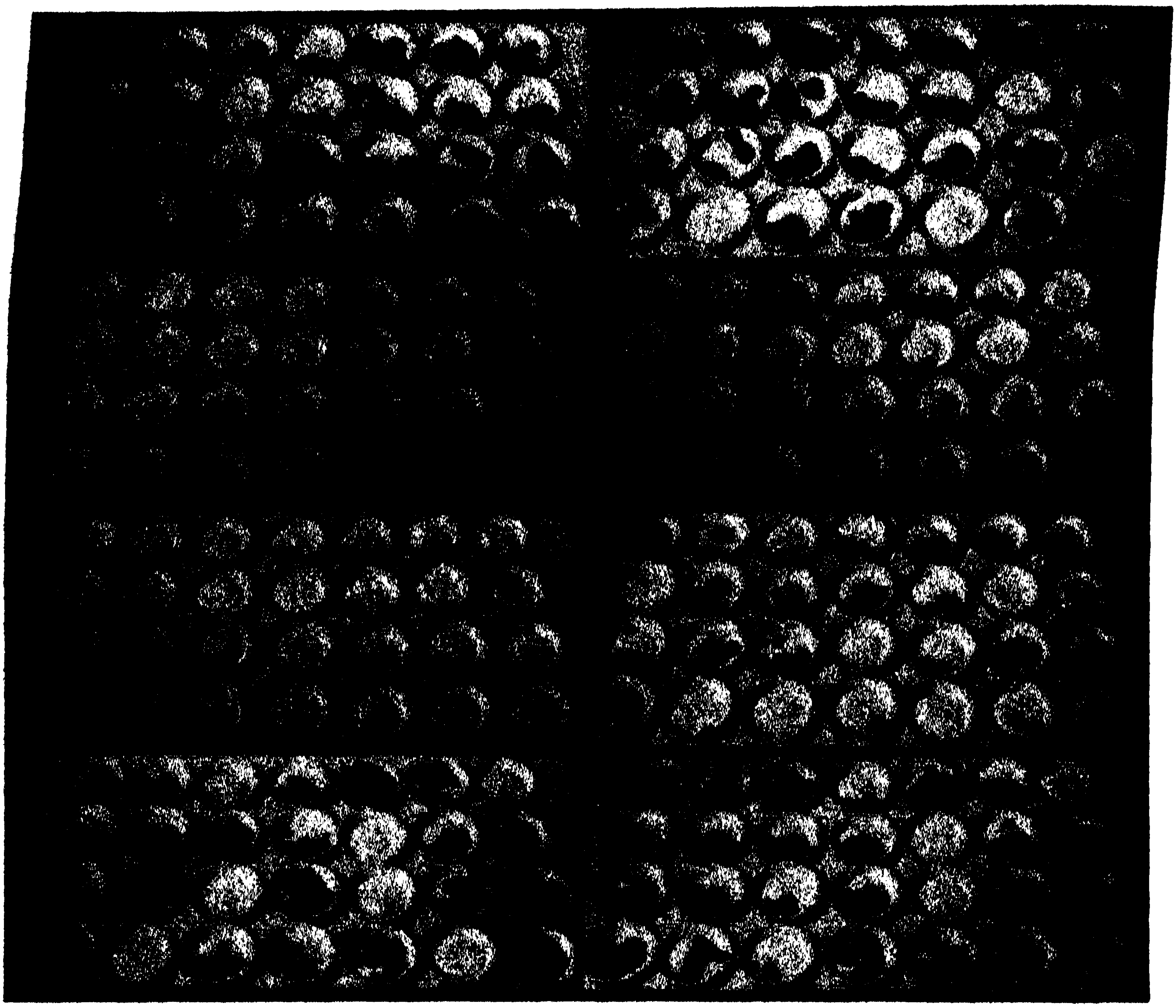
The farmer, the horticulturist and the gardener, however, take environment well into account. They have learned to manipulate it in all sorts of ways: through the use of fertilizer, through irrigation, drainage, the use of shade where necessary or winter protection; also by altering the physical composition of the soil, by regulating the time of planting, by various methods of storing the seed, by spraying, dusting, and so forth. Some striking examples of large-scale modification of environment are the use of shade in cacao plantations, orchard heating and the planting of windbreaks and shelterbelts.

But this regulation of external conditions surrounding the development of a plant can only be carried to a certain point. There are limits beyond which the most skilful agriculturist and gardener can not go. In extensive farming, particularly, comparatively little can be done to furnish the acres and acres of crop plants with the exact conditions that each particular variety may require. Also, by manipulating some one factor in the environment, an existing balance may be easily upset whereby the resulting harm may exceed the benefit attained. It remains, then, for the geneticist, the



MODIFICATION OF ENVIRONMENT

ON A LARGE SCALE. A TEA PLANTATION IN THE CAUCASUS WITH SILKTREES (*Albizzia julibrissin*) PLANTED FOR SHADE TO INDUCE THE FORMATION OF LARGED-SIZED, DARK-GREEN LEAVES.



YIELD VARIATION

IN TWENTY-EIGHT INTRODUCED SOUTH AMERICAN POTATO VARIETIES GROWN UNDER VARIOUSLY MANIPULATED ENVIRONMENTAL FACTORS OF LIGHT AND TEMPERATURE.

plant breeder, to produce varieties that will embody in their genetic make-up the proper combination of factors that will respond favorably to the given environment.

Desirable Characters

A mere mention of the principal characters sought by both the plant introducer and the geneticist will plainly show the close connection between these characters and the environment. In cereal crops and forage grasses, as well as in fruit and in vegetable crops, the search is mostly for disease resistance, drouth and cold resistance, earliness of maturity and palatability, all coupled with high yield; in drug and insecticide plants and other similar crops, it is chemical composition, easy extractability of the desired ingredient; in ornamentals, in addition to cold, drouth and disease resistance, it is, perhaps, abundance of bloom, fragrance and seasonal dependability.

There is plenty of evidence that all these characters are controlled in inheritance by genes. It is equally certain, however, that their final expression is guided by the conditions under which the plant is grown. While we know very little of the mechanism for the expression of genetic factors in general, it is quite obvious that in the expression of the factors enumerated above, it is soil, tem-

perature, precipitation and other manifestations of the surrounding medium that play a dominant rôle.

Plant Introducer's Task

To the plant introducer this means that in addition to finding a plant with the desired character, which is a difficult enough task in itself, he must make an exhaustive study of its native habitat and find the relationship between the particular character and the environment. After introduction a plant must be tested under various sets of conditions and its behavior carefully observed before it can be made much use of either directly or by plant hybridizers.

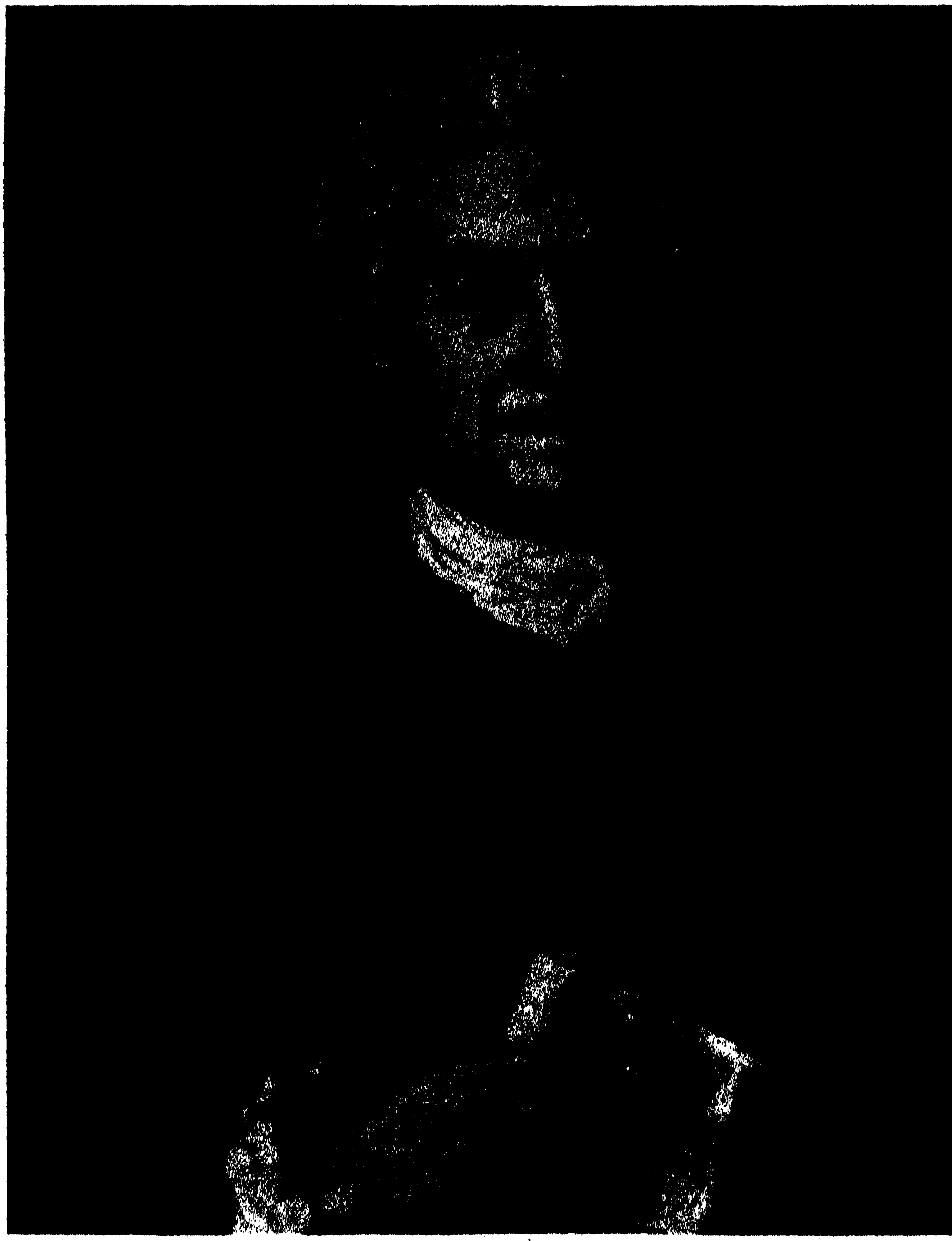
Plant Breeder's Task

There is no sharp dividing line to indicate where the plant introducer's work should end and that of the breeder should begin. Nor is it possible to carry out any crop improvement project satisfactorily without the aid of the taxonomist, the physiologist, the plant ecologist, pathologist or others, depending on the particular problem involved. The breeder's job is to bring about a proper "match" between genetic factors and environment, to fit the former into the latter so as to incorporate both, so to speak, into the ultimate, properly balanced system. Assuming that he is working with one of the characters mentioned and that he is concerned with a definite environment, he must analyze the factor for its response to that environment.

In the case of simple Mendelian characters, mostly morphological in nature, the shuffling of genes and ordinary methods of genotypic attack may suffice. But, in the case of the characters mentioned, some additional means must be used for the proper evaluation of both the parental stock and the resulting progeny. Such characters as disease resistance, drouth and cold resistance, chemical composition and so forth rarely are simple. Disease or insect resistance, for example, has sometimes been shown to be due to shape of leaf, thickness of epidermis, rapidity of growth and chemical and metabolic phenomena. Breeders for disease resistance who attempt a short cut to the solution of their problem soon discover its great complexity. Furthermore, as stated above, the phenotypic picture will be modified by the environment in which it is expressed.

Evaluation of Introduced Plants

Progress has been made in technique for analyzing the genetic constitution of plants as affected by variation in specific elements of the environment. The creation of disease epidemics under more or less controlled temperature and humidity; studies of response to differences in length of day or to extremes of temperature or moisture are examples. There is ample room, however, for further progress in the development of such objective techniques, and this is particularly important to the more efficient use of plant introduction in connection with plant breeding. The breeder in a given environment can evaluate his stocks for that environment. A catalog of the responses of introduced relatives, whether varieties, species or genera, to environmental elements in general should make plant introduction an even more important adjunct to plant improvement.



EMANUEL SWEDENBORG

EMANUEL SWEDENBORG

By Dr. JOHN R. SWANTON
SMITHSONIAN INSTITUTION

THE two hundred and fiftieth anniversary of the birth of Emanuel Swedenborg, which occurred on January 29, 1688, and is being widely celebrated by his admirers, renews attention to one of the most remarkable characters of history, a man so many sided that he made distinguished contributions to several branches of science, aided materially in advancing the industries of his native Sweden, and attained distinction as a philosopher and theologian. On one and the same day he could lead the conversation with geologists, physicists, physiologists, metallurgists, engineers, statesmen, philosophers—and angels.

Swedenborg was descended on both sides from families intimately connected with the mining interests of Fahlun, in the present Kopparberg Province, but his own father, Jesper Swedberg, many of whose characteristics he shared, was a successful minister of the state church who finally rose to the position of Bishop of Skara, was known as a poet and philologist, and noted for his breadth of view, his utter fearlessness and his earnest endeavors to promote education. His attempts to improve the Swedish hymn and psalm book served to bring upon him the charge of heresy. Heretic or not, he was popular with his sovereigns and was ennobled together with his family by Queen Ulrica Eleonora in 1719, the family name being then changed from Swedberg to Swedenborg.

Emanuel graduated from the University of Upsala in 1709 and soon afterward made the acquaintance of Christopher Polhem, the greatest Swedish engineer of his time, whose favorite he soon became. In 1710 he visited England bent upon the pursuit of scientific studies then advancing rapidly in the United Kingdom under the stimulus supplied by Sir Isaac Newton whose works he studied daily, and he made the acquaintance of Flamsteed, Halley and Woodward, through whom he was introduced to other members of the Royal Society. His thirst for learning at this time appears to have been unquenchable. Not merely was he an omnivorous reader, but he was in the habit of boarding with various craftsmen and learning from them their several trades. In Sweden he had already acquired the art of bookbinding and made shift to play the cathedral organ. In London he added in this way some knowledge of watchmaking, cabinetmaking and the making of mathematical instruments. Later, in Holland, he learned how to grind lenses for microscopes. But he devoted most of his time to mathematics and astronomy and also acted as agent for the small group of men in Sweden who were beginning to interest themselves in scientific studies. He returned to his own country in 1715 after about two years in England, visiting on the way Holland, France and northern Germany, his enthusiasm for scientific work throughout that period being evidenced by his correspondence with his brother-in-law, Eric Benzelius, librarian of the University of Upsala. From these letters it appears that his mind was also busy with attempted inventions, and among them he mentions a submarine, a hydraulic engine, a new type of lock, a fire engine, a machine gun, a mechanical musical instrument, a mercury air-pump and an airship. Of the last of these, which he was frank enough to recognize as at that time unworkable, we have a drawing and description. The air-pump is said to have been the first to involve the use of mercury. He was particularly en-

grossed with "a new method of determining the longitude of places by means of the moon."

Returning to his native land full of plans for the promotion of learning, he found his efforts constantly thwarted by indifference, vested interests and shortage of funds due mainly to the imperialistic enterprises of Charles XII. He was particularly disappointed at the opposition of the mathematicians and remarks of them:

It is a fatality with the mathematicians that they remain mostly in theory. I have thought that it would be a profitable thing if to ten mathematicians there was added one thoroughly practical man, by whom the others could be led to market; in which case this one man would gain more renown and be of more use than all the ten together.

Which goes to show how times have changed.

Although thwarted in this direction, Swedenborg went to work industriously to establish a scientific journal, the first number of which came out in 1716. It was called *Daedalus Hyperboreus* and lasted until 1718, though only six numbers appeared in all. The year in which the first of these saw the light he was given a position on the Board of Mines which had supervision over the great mining industries of the country, but he was only an "extraordinary assessor," serving without salary, and in the early years of his incumbency he was detached at times for special services under Polhem. The most striking of these was the transportation overland from Stromstad to the Iddefjord, a distance of fourteen miles, of two galleys, five large boats and one sloop, to assist Charles XII in the siege of Fredrickshald (now Halden), Norway, in 1718. The enterprise was carried through under Swedenborg's immediate supervision. He was engaged similarly in the construction of the great dock at Carlscrona and on the North Sea-Baltic Canal, the latter left unfinished at that time, owing to the death of the king.

Besides the activities above enumerated he was busy with a scheme for the extensive production of salt in Sweden, plans for a new slow-combustion stove, a new method of detecting mineral veins and a decimal system of coinage and measures, but he found, like many another progressive before him, that, in his own words, "speculations and arts like these are left to starve" and "are looked upon by a set of political blockheads as scholastic matters, which must remain in the background, while their own supposed refined ideas and their intrigues occupy the foreground."

Thoroughly disgusted with this attitude toward the newer learning in the land of his birth, Swedenborg now thought seriously of seeking his fortune abroad as a mining engineer, but instead, in 1721, set out on a journey to Holland and Germany in the interest of the Board of Mines, and he visited all the workings in Saxony and the Hartz Mountains. Upon his return the year following he laid before the board and the king simultaneously proposals for increasing the yield of copper from the ore, for improvements in the manufacture of steel, and for the removal of the handicap then placed upon iron by a short-sighted distinction between that metal and copper according to which the latter was classified as "nobler" and favored accordingly. He expressed a belief, contrary to the uniform practice of the time, that "there ought to be no secrets at all in metallurgy."

In 1724 Swedenborg was appointed a regular salaried "assessor" of the Board of Mines, and the same year Sir Hans Sloane invited him to send contributions on metallurgy to the Brtish Royal Society. He pursued the duties of his office with characteristic energy, and in 1734 some of the results of these labors appeared in the form of three heavy folio volumes entitled "Opera Philosophica et Mineralia," two of which contained treatises on copper and iron, respectively, and gave him immediately a European repu-

tation, parts being translated into French and German and reprinted in those languages. The first of the three, however, received more enduring attention as the earliest attempt to set forth a theory of cosmic evolution similar to that later made familiar by Laplace under the name of "the nebular hypothesis." In 1740 Linnaeus invited him to become a member of the Royal Academy of Science of Sweden, which had been founded the year before, and he was also made a corresponding member of the Academy of Sciences of St. Petersburg.

Swedenborg's narrative of his visit to Germany to have the "Opera Philosophica" printed—it appeared in Dresden and Leipzig—reveals an insatiable curiosity, but a mind primarily attracted by mechanical processes and rather markedly deficient in the esthetic faculty, a common fault of the period. He visited libraries, museums, picture galleries, churches, monasteries, asylums, theaters, but especially manufactories, and his notes concern mostly scientific matters, such as mining; blast furnaces; vitriol, arsenic and sulfur works; naval architecture; copper and tin manufactures; paper mills; plate glass and mirrors; magnetism; and hydrostatics. He was interested in things "practical" and scientific rather than in antiques or in painting and sculpture. He was abroad again from 1736 to 1740 and 1743 to 1744, and his diaries covering these years contain many interesting items, including an expression of admiration for republican government as exemplified by Holland as opposed to monarchies, an expression all the more remarkable since he and his family had little reason to complain of their treatment by the sovereigns of Sweden.

II

As a principal object in each of these journeys Swedenborg had in mind the publication of a bulky work, the first of which has been translated into English as "The Economy of the Animal Kingdom" and the second as "The Animal Kingdom." These names obscure, however, the purpose which the books subserved and the character of the investigation upon which their author had embarked. As far back as 1719 he showed his interest in the nature of organic life by submitting to the Royal Medical College a small treatise entitled "The Anatomy of our Most Subtle Nature Showing that our Moving and Living Force Consists of Tremulations," and this interest possessed him so completely by the time he had published the "Opera Philosophica" that he devoted more and more time to it, undertook dissections himself, and began to collate materials from the writings of the great anatomists and physiologists of the period, including such men as Baglivi, Boerhaave, Eustachius, Harvey, Leeuwenhoek, Malpighi, Morgagni, Swammerdam and Vieussens, men famous in the history of science and many of whose names are connected with organs in the human body. The enterprise he had in mind was similar to that which moved the founders of the science of psychology, even though psyches are now out of fashion in that discipline. In brief, Swedenborg proposed to himself a thorough-going attempt to attain to a knowledge of the soul by studying its manifestations in the human organism. This purpose is at once revealed in the correct translations of the titles of the two works just mentioned which should read, "The Economy of the Soul Kingdom" and "The Soul Kingdom."

In pursuing this work, Swedenborg drew more, ostensibly at least, from the writings of others than from his own investigations, with the deliberate intention of correcting any tendency toward personal bias in the interpretation of organic phenomena. His method of presentation was to place first quotations from the authorities of his time on some fluid of the body or some organ, attempt an induction from the mass of evidence as to its functions and its relation to the other parts of

the body, and finally take up his induction sentence by sentence and support each in turn with confirmatory evidence. This was a favorite system which he employed throughout the remainder of his life. The works just metioned represent two different approaches. In the first period he was interested mainly in the fluids of the body, in the second he was rather concerned with separate organs. In fact, his literary remains show that he changed his plan several times, and, besides the published works, he left in manuscript a huge amount of material which was to have gone into other portions, some of which has been printed since his death, while other documents are still in the shape in which he left them, although nearly all have now been photocopied to insure preservation.

III

Between 1743 and 1745 occurred the psychological break in Swedenborg's life which has attracted the greatest attention to him and may perhaps be said to have made him more noteworthy than famous. His first period closed with a work in semi-poetical style entitled "The Worship and Love of God," in which he attempted to present his philosophical views in a unified form. Immediately afterward came the long series of writings on which rest his claims as a theologian. Meanwhile, alongside of his scientific, philosophical and now theological activities, he was energetically interesting himself as a member of the House of Nobles in the activities of the Swedish Diet. His proposals for the improvement of mining have already been mentioned. In 1734 he strongly opposed entering upon a war against Russia, advocating instead measures to build up the internal prosperity of the country, and in 1741–43 his judgment was vindicated when the war party prevailed and Sweden was nearly ruined in consequence. In 1755 came a memorial on the liquor traffic, the substance of which is given in the following paragraph:

If the distilling of whiskey—provided the public can be prevailed upon to accede to the measure—were farmed out in all judicial districts, and also in towns, to the highest bidder, a considerable revenue might be obtained for the country, and the consumption of grain might also be reduced: that is, if the consumption of whiskey can not be done away with altogether, which would be more desirable for the country's welfare and morality than all the income which could be realized from so pernicious a drink.

In 1760 he presented several memorials on the currency, and, in the most important of these, after advocating several minor measures, he concludes:

But all are of little value, except one, which consists in returning to a specie currency, such as existed in Sweden heretofore, and as exists in all countries of the world: for in specie itself lies the real value of exchange. If any country could exist by means of a paper currency, which signifies money, but is not money; such a country would be unparalleled in the world.

From 1745 until his death in London on March 29, 1772, he continued indefatigably the writing and publishing of his theological works, which, including unpublished manuscripts, number eighty-three titles, while his papers on science and natural philosophy number about one hundred and twenty. The former brought into existence the religious body usually known by his name, Swedenborg having been, I believe, the only man with claims to scientific eminence who founded a religious sect. It may be added that he himself took no active part in the foundation and died before it came into existence. His body was interred in the small Swedish church in London and remained there until 1909, when it was taken back to Sweden in a war vessel with national honors and finally placed in a sarcophagus in Upsala Cathedral, unveiled by H. M. Gustav V, King of Sweden, on November 19, 1910.

IV

Some idea has already been given of the considerable debt which the promotion of science in Sweden owes to this "visionary." One of his early ambitions was the foundation of a "Society for

Learning and Science," another the establishment of a chair of mechanics at the University of Upsala, and, in conjunction with his brother-in-law, he earnestly advocated the erection of an astronomical observatory at the same university. He prepared the first work on algebra to appear in the Swedish language, which shows his interest in promoting the study, though the work itself is not of much distinction. His plans for a mercury pump and the improvement of stoves are said to have involved important technical advances but for lack of sufficient research it is impossible to say for precisely how many innovations he was responsible. There can be no question, however, that the great mining enterprises of Sweden were very greatly advanced by him, partly through the publication of the results of his researches in copper and iron, partly by his advocacy of the introduction of rolling-mills into Sweden, and partly by his recommendation that the handicap already mentioned be removed from iron.

V

It is not easy to enumerate Swedenborg's own contributions to science. It will be sufficient to quote the remarks of scientists in a position to express opinions in their several fields. Thus, the chemist Jean Baptiste Dumas says: "It is then to him we are indebted for the first idea of making cubes, tetrahedrons, pyramids, and the different crystalline forms, by grouping the spheres; and it is an idea which has since been renewed by several distinguished men, Wollaston in particular." Van't Hoff also commends his work as prophetic of the science of stereo-chemistry, of which he himself was such a distinguished exponent. Svante Arrhenius thus summarizes the results of his own investigations:

> If we briefly summarize the ideas, which were first given expression to by Swedenborg, and afterwards, although usually in a much modified form—consciously or unconsciously—taken up by other authors in cosmology, we find them to be the following:
>
> The planets in our solar system originate from the solar matter—taken up by Buffon, Kant, Laplace, and others.
>
> The earth—and the other planets—have gradually removed themselves from the sun and received a gradually lengthened time of revolution —a view expressed by G. H. Darwin.
>
> The earth's time of rotation, that is to say, the day's length, has been gradually increased—a view again expressed by G. H. Darwin.
>
> The suns are arranged around the Milky Way —taken up by Wright, Kant, and Lambert.
>
> There are still greater systems, in which the Milky Ways are arranged—taken up by Lambert.

Professor A. G. Nathorst, superintendent of the State Museum for Fossil Plants at Stockholm, praises Swedenborg very highly for his contributions in the field of geology and particularly commends him for having made the observation that the Scandinavian Peninsula is rising. Swedenborg saw, he says, "that many phenomena which testified to a higher water-level in former times did not arise from the so-called universal [Noachic] flood, and this in itself involves a step forward in the direction of complete liberation from the dogma which had prevailed up to that time, and which had exercised such a restrictive influence on the development of geology."

Professor O. M. Ranström, professor of anatomy in the University of Upsala, remarks, "As is well known, Swedenborg, by his investigations, obtained an insight into the fact that it is the surface of the cerebrum, the grey cortex of the brain, which serves as the material basis of psychical phenomena"; and Dr. Gustav Retzius, in his address as president of the Congress of Anatomists, delivered at Heidelberg on May 29, 1903, repeats the above in substance and adds, "Swedenborg . . . has not only predicted the localization of the motor centers of the cortical substances, in harmony with the views gained from pathological and physiological experiences during the latter half of the past century, but he has even on the

whole correctly pointed out the seat of these centers!"

These statements are endorsed by Professor Max Neuberger, professor of the history of medicine in the University of Vienna, who in 1910 said, speaking of the results of some of Swedenborg's physiological researches, "If we examine these results we are forced to admit that, regarded from the point of view of modern knowledge, they surpass nearly everything that is to be read elsewhere on this subject in the writings of the eighteenth-century authors."

More recently a reviewer of the new edition of Swedenborg's work on "The Brain" writes in *The Lancet* (April 6, 1935):

> He ascribes the motor areas of the brain to the positions now known to be the correct ones, even to the relative positions of the areas controlling the head, arms, trunk, and lower limbs. He also locates the intellectual faculties in the frontal region of the brain. In common with many philosophers of his time, he was much troubled about what part of the brain was occupied by the "soul"; he discarded entirely the theory of Descartes, largely held at that time, that the "soul" resided in the pineal body, but ascribes it rather to the cortex of the brain. From an analysis of the minute structure, as then known, of the pituitary gland, he was led to ascribe to it functions of the utmost importance in the composition of the blood, and, in fact, calls it the "arch gland" of the body.

It may be added that in his "Principia," if not before, Swedenborg set forth the idea that heat is a mode of motion. He also has the merit of proposing a compound and "soft" atom instead of the "hard" atom of Newton and he adopted the undulatory theory of light of Huyghens instead of the corpuscular hypothesis of Newton. The "points of pure motion" which he makes the ultimates of matter suggest the later theory of Boscovich.

Strange as it may seem, some of the opinions advanced by Swedenborg after the time when he was accused of insanity by his contemporaries represent distinct advances over those previously held by him and by the students of his day. While certain of these are of a philosophical and theological character, there are instances which concern the scientific field. Thus, in his earlier writings he had attempted to reconcile his theory of terrestrial evolution with the letter of Scripture in the matter of the Noachic flood by supposing that the earliest solid land surface was formed over the waters after the manner of ice, that organic life arose and flourished upon this crust, that upon it Adam and Eve were created—though even then he balked at the literal narrative—and that the breaking up of this crust was meant by the Biblical words "and the fountains of the great deep were broken up." But in the "Arcana Coelestia," the first of his strictly theological works, he avers that the first chapters of Genesis are not to be taken verbatim, that no literal deluge was meant, "still less a universal deluge," and that there were "preadamites" who lived "like wild beasts" before the dawn of civilization.

It is to be observed that some of Swedenborg's contributions to knowledge above noted have reference to human ideas regarding knowledge rather than to knowledge itself, and it is the writer's impression that the main contribution of this remarkable Swede was in aiding the transition from catastrophic theories of the creation of the cosmos to the modern evolutionary position. In explanation of this statement it must be said that Swedenborg was practically the first thinker to suggest a development of the cosmos in time in an orderly sequence in accordance with natural law. Professor Magnus Nyrén, writing in the *Viertlejahrschrift der Astronomischen Gesellschaft* (Volume XIV, 1879), says:

> It can not be denied that the essential part of the nebular hypothesis, namely, that the whole solar system has been formed out of a single chaotic mass, which first rolled itself together into a colossal ball and subsequently by rotation broke up into several parts and finally contracted into the planetary masses, was first expressed by Swedenborg.

This has been recognized by many other scientists and should be self-evident from an examination of Swedenborg's "Principia Rerum Naturalium" and a comparison of the date of its publication (1734) with that of Kant's "Allgemeine Naturgeschichte und Theorie des Himmels" (1755) and Laplace's "Exposition du système du monde" (1796). It is to be added that Laplace professed to have had the idea of the nebular hypothesis suggested to him by Buffon, and a copy of Swedenborg's "Principia" is known to have been in the latter's library.

This work must be weighed, not in the exacting scales of the science of our time but with reference to the crude observatoins and the crude instruments upon which they depended in the infancy of modern science. The bases of Swedenborg's attack were sound, since he postulated "experience," in which he included experiment and a rational systematization of the facts of experience. He attempted to found his theory of leasts, "the corpuscular theory" as he calls it, on studies of the behavior of liquids, salts and metals, and his general cosmic theory on the phenomena of magnetism. He was inspired, as well as handicapped, by Descartes's conception of vortices, and it can not be said that he showed scientific penetration in handling the mathematics and mechanics involved in his theory. He is remarkable for qualitative conceptions rather than mathematical realizations. For a brilliant treatment from this point of view the world had to wait for Laplace, and even then the resulting hypothesis was ultimately found defective. Swedenborg's hypothesis was, however, superior to that of Kant in that it assumed motion at the beginning, and in one particular it went behind all later theories in attempting to gather into one evolutionary process not merely the mineral and gaseous substances, but the media in which light and electricity, magnetism and gravitation reside, which he assumed to be connected with spheres of varying degrees of subtlety, and imagined the most subtle had produced the grosser in successive order. Workable or not, the theory had a phenomenal basis for each of the entities introduced into it. But although Swedenborg represents prior elements as entering into and constituting those more inert, in his final treatment he points out that the apparently simple is itself immensely complex and far more active than the "corpuscles" built out of it. Thus, he practically arrived at the conclusion that inorganic evolution is a kind of limiting or stopping down of forces and that in plant and animal organisms these are progressively released. This suggests rather strongly the "unpacking" process of evolution of Bateson.

In his treatment of the origin of organic life our author was hampered, however, by the theology of his time and the limitations it placed upon sidereal and terrestrial chronology. He compared the original nebular mass out of which the solar system arose, and again the earth itself before organic life came into existence, to an egg, but for the reason just given, was unable to carry out this productive thought to its logical conclusion, and the nearest he got to organic evolution is perhaps in the following passage from "The Worship and Love of God":

> This virgin and new-born earth, furnished with so becoming an aspect, now represented a kind of new egg, but one laden with as many small eggs, or small seeds, collected at its surface, as were to be of its future triple kingdom, namely, the mineral, the vegetable, and the animal. These seeds or beginnings lay as yet unseparated in their rudiments, one folded up in another, namely, the vegetable kingdom in the mineral kingdom, which was to be the matrix, and the animal kingdom in the vegetable kingdom, which was to serve as a nurse or nourisher; for each was afterwards to come forth distinctly from its covering. Thus the present contained the past, and what was to come lay concealed in each, for one thing involved another in a continual series.

This passage is as pregnant with possibilities as Swedenborg's new-born

earth, but in his thought it took the direction of a parallel evolution of species from particular vegetable forms directly to particular animal forms, and the possibilities remained unrealized by him. This parallelism was due in part to the fact that he believed that plant and animal organisms were divided into great classes depending upon a close connection with the air, the ether or the magnetic or gravitational element, those related to the subtler elements being higher in the scale. With all its shortcomings, this theory of Swedenborg's presented a picture of cosmic unfoldment, particularly in its earlier chapters, which marked a distinct step toward the systems of natural evolution that were so soon to follow and there is good reason to believe helped to bring them into existence.

VII

The fact must not be lost to sight that a unifying thread runs through Swedenborg's cosmic views from 1717, when he penned a few brief paragraphs "On the Causes of Things," until the end of his career. The later works amend and change the applications of his cardinal principles but do not abolish them. One of these is the doctrine of series and degrees based on the assumption that gravitation, magnetism, light and sound exist in elements of progressively less subtlety, the lowest being the atmospheric air, and that they originally came into existence in this order, that because they are composed of substances from these elements there is a similar differentiation among minerals, plants and animals. This creation of the grosser out of the subtler and subsequent modification by the subtler gives us the doctrine of influx. Instead of approaching simplicity, however, as we ascend the ladder of degrees, we are really coming to more complex entities, or at least entities with greater potentialities, and therefore we have immense varieties in the mineral kingdom and still greater varieties in the vegetable and animal worlds. Each specific variation in any of these kingdoms has its reason for existence, not its immediate cause, in something in a higher degree to which it corresponds, and this is his doctrine of correspondences. The forms which minerals and organisms have depend upon their lesser or greater correspondence with reality itself or God who is to be conceived of, not as personal or impersonal but as superpersonal, inorganic substances being the most remote and partial reflections of deity, vegetable species a closer reflection, animal species a still closer reflection, and men the closest of all. Individual men are themselves but partial reflections of the great reality and so tend to become linked together into larger and larger bodies through division of functions, the sum total of which is an increasingly more perfect image of deity. This is the doctrine of the greatest man. Of course this discussion has led us into theology, but it has been necessary in order to give something like a total view of the position of Swedenborg in the world of natural and spiritual philosophy.

Crude as the above exposition has been, it will perhaps explain in some measure why Swedenborg has been found worthy of respectful, often of enthusiastic, consideration by thinkers as diverse as Balzac, Coleridge, Carlyle, the Brownings, Coventry Patmore, Emerson, James Freeman Clark, Phillips Brooks, Henry James, Sr., August Strindberg, Theophilus Parsons, John Bigelow, Helen Keller, Edwin Markham and many more. He was first widely known as a theologian and for his placid and unruffled claims to spiritual illumination, publicized by such works as Kant's "Dreams of a Spirit Seer" and Emerson's essay on "The Mystic" in "Representative Men." Only at a relatively recent period have students been aware of the immense volume of scientific and philosophical study which went before.

SOME ASPECTS OF THE LIFE OF A SCIENTIST

By Dr. MAURICE C. HALL
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THE life of a scientist is only too obviously just like the life of any other human being in almost all respects. Some of the few respects in which it differs, to some extent, from the customary patterns of life among other groups, are the ones to which we wish to invite attention. The rambling selection of ideas is on the basis of interest rather than on unity of composition.

In its purer aspects, the scientist is in the enviable status of a person who is paid real money to satisfy his childlike curiosity. In this status he is one of God's eternal children, a child who may continue to ask What and Where and When and How and, especially, Why, as long as he lives, and who is graciously permitted and encouraged and assisted to try to find the answers to his questions. It is hard to detect any flaw in such a mode of life, although it is easy to detect flaws in ourselves as scientists in our attempts to follow this mode of life. Perhaps the greatest flaw is the underdevelopment of our curiosity. Perhaps as children we have had our hands smacked or have even been paddled for our curiosity so often and so hard that it has blunted the fine edge of our originally keen and endless desire to ask questions and to have them answered. Under the happiest of research conditions, such as the author has seen but few times and for short periods, research moves with a sparkle and crackle of questions jumping from every day's findings, and the mind moves questingly in all directions in search of explanations for this and that, with plans building up like a snowball. We experience then those fine moments when a half hour's conversation with an enthusiastic colleague sees a five-year program develop, and with it the intense realization that every week spent on carrying out that program will raise questions that will require yet other five-year programs to answer. Such fine moments are too rare. It is not permitted the human mind to function often with such efficiency. Fatigue or indigestion, committee meetings or budgets, incompatible personalities or competitive activities, or other things adverse to clear and quick thinking apply the brakes to our minds too often and too well, and we live for the most part on the lower levels of intellectual life, and follow the ruts of mental patterns, automatic activities and reflex actions that can not well be termed intellectual.

It has seemed to the writer that a very large proportion of the scientific literature with which he is familiar, including most of his own production, is definitely unsatisfactory. At times he has felt that a lack of curiosity is the principal reason for the inadequacy of the work published, but at other times he has felt that it is the depressing effect of the concomitant conditions secondarily associated with scientific work or with part of human life in general that is responsible. Any one with the instincts and equipment of a scientist, and in a somewhat normal physical and mental condition, must find research stimulating, but the scientist's routine life inevitably lowers the response to the stimulus. In the colleges, research must wait on teaching, but classes must meet on schedule. Letters must be answered, and correspondence, which, theoretically, might be an exchange of interesting ideas, is found to be mostly the dull business of answering questions and often of answering what

might be termed "fool questions." Large slices of life are eaten away in what are politely termed interviews but which are usually time-consuming and profitless conversations.

All these things not only limit research activities in the laboratory, but effectively abbreviate and depreciate the important business of thinking. We are all familiar with the scientist who is endlessly active, but who seems to gallop all day on a ten-cent piece like a diminutive broncho plunging about endlessly and getting nowhere. Too evidently, such scientists are not indulging in the business of thinking and especially of asking questions as to the meaning of things and the planning of sound procedures to answer these questions. It should be axiomatic that the scientist must have time to think. His translatory activity in the laboratory, unsupplemented by adequate thought activity, is equivalent to driving madly through the night across the prairie without headlights on his car and is likely to terminate in such accidents or such arrivals at or near his point of departure as find their way into scientific papers to the distress of all critical minds. Such papers seem equivalent to the "Local Items" in the country newspapers. Thinking is the searchlight which enables us to see where we are going, and to perceive such sideroads as should be noted for subsequent exploration, and too obviously most of us are following established modes of research most of the time without much of what could be properly termed real thought.

The evident explanation for this is that some of us have too few of the essential characteristics of scientists or have those characteristics too little developed, and that some of us, and I think almost all of us, are trying to carry out research under conditions that make sound research difficult and sometimes impossible. Very few of us have a status which is solely, or even primarily, that of a research worker. Only a few scientists are so equipped and in such a position as to make an intelligent selection of their own problems, to attack them intelligently in their own way, to devote to them all their time and energy so far as this is necessary or desirable, and to continue their investigation for years with the objective of well-rounded research.

In a book by Ramon y Cajal on rules and advice for scientific investigation, a book which should be required reading for graduate students, the distinguished Spanish scientist discusses the characteristics of science and scientists. A section is devoted to love of fatherland as one of the motivating forces of the scientist, and the idea is there expressed that in one way and another science will bridge the gaps between nations and promote better understanding. In the 1933 German edition, Ramon y Cajal has a footnote to the effect that the world war has contradicted his ideas. To-day, the scientist who has believed that his research was for the benefit, not merely of fatherland, but of mankind, and who has rejoiced that scientists, at least, had free trade in ideas, is confronted with the incredible notion that science is divisible into national and racial divisions, as though the value of gravity in any country might vary with a form of national government rather than with the government of natural law. To the extent that politicians believe in such enchantments dominating natural law, one may say, " 'Tis a mad world, my masters," but when any scientists subscribe to such magic, all other scientists must feel depressed.

By virtue of specialized training under specialists, we have Johns Hopkins scientists, Yale scientists and similar groups, and even schools of thought that follow from temporary tendencies to adhere to this or that theory in default of conclusive evidence establishing theories generally concurred in, but we decline to

believe that there can be a French or German science, a Michigan or Ohio mathematics, a Chicago or Omaha zoology or a Methodist or Baptist geometry. When metaphysics abandoned the authoritarian method it developed into modern science, and when modern science anywhere accepts the authoritarian method it again becomes metaphysics. Unless we can accept the universality of natural law, the working of proportionate cause and effect, and the possibility and necessity of scientists anywhere checking the work of other scientists under different environments in order to rule out personal, local and incidental factors, we might as well abandon science and take up theology or some other subject in which the dicta of authority are accepted as *ex-cathedra* statements of fact. Even less than most groups, scientists can not serve two masters. They can not march with the scientists of the world in the search for ultimate reality and truth, and at the same time be regimented and drilled by politicians in some magician's maneuvers in nationalistic science.

One of the less pleasant aspects of the life of a scientist engaged in medical research is the result of a theory among commercial houses, business firms, chambers of commerce and other groups to the effect that the facts in scientific and medical publications may be commercialized and exploited, usually without thanks or remuneration to the authors of the publication, whenever such commercial development is possible, but must be suppressed, and the authors, if possible, punished and harassed whenever the facts indicate that there is any flaw in our mode of living and doing business which might in any way injure business. The sequence of events may take the following form:

A scientist publishes a paper indicating that a certain disease is spread by eating certain kinds of food or reads a paper to this effect. While the paper may be intended for scientific and medical groups, it comes more or less inevitably to the attention of the public by way of newspapers and other non-scientific publications, necessarily in incomplete and sometimes distorted form. Although the scientist does not write these articles, some business interest which believes its profits are likely to be lessened or its business curtailed, even for a short time, as a result of the press bringing the findings to the attention of the public, immediately attacks the scientist on all possible grounds. One attack takes the form of trying to bring to bear on him such pressure, political or otherwise, as will stop his work, interfere with his sources of material, or otherwise prevent any further fact-finding activities. Another takes the form of searching for other scientists who may in any way disagree with the first one, and trying to obtain from them statements which will tend to show that the first scientist is incompetent or mistaken, and too many scientists, consciously or unconsciously, lend themselves to this form of handicapping the work of their colleagues. Another attack takes the form of creating prejudice against the scientist by selecting from his papers items which will indicate that his procedures, known to scientists as routine laboratory procedures, violate established conventions or taboos of some sort. The final maneuver is an attempt to oust the scientist from his job, which procedure has at times taken the form of bills in Congress. You will recall the classical attacks on Harvey Wiley and Gifford Pinchot, which attacks are extensions of a fight on scientists to a fight on their employers, their superior officers or their organizations.

These business interests assume that they can place a valve on the movement of scientific information in such a way that profit-making articles may be put

into circulation or otherwise capitalized, and that profit-diminishing articles may be kept out of circulation and away from the public. Obviously, this assumption runs counter to the trend of the times. There is a growing demand that scientific facts be given such interpretation as will bring them to the attention of the public in simple and understandable form. To achieve this we have such services as Science Service, the publicity section of the American Association for the Advancement of Science, and special scientific writers in the press services and elsewhere. Sooner or later the business world must accept the idea that when scientific research points out conditions menacing to public health, business must cooperate in carrying out its share of control measures and permit others to carry out theirs, rather than to attack the scientist and his work. It was said long ago that nothing is so easily frightened as a million dollars, but even admitting this we must ask that business men refrain from trying to suppress facts on the implied assumption that sales and profits are more important than public health, and dollars more important than life. Scientific facts can hardly be termed education and popularization of science at one time, and be termed undesirable publicity at another. In a country that has the guarantee of free speech and a free press in its constitution, the idea that science must be supervised by business, and that business must "put the heat" on the scientist when his findings are not to the liking of business, is peculiarly unwholesome. The pressure of advertisers in keeping out of the press news items regarded as unfavorable to business, by the threat of withdrawing advertising, constitutes a curb on a free press, and so does the action of business interests in suppressing information in regard to epidemics in cities on the ground that it might prevent tourists or others coming to these cities. This latter is equivalent to inviting travelers to risk their lives and health by entering a danger area without warning in spite of a knowledge of the danger by those who should bring it to the attention of the public.

In all this there is evidence of too much short-range thinking and too little long-range thinking. Obviously, the suppression of essential facts delays the application of remedial measures which tend to put business on a sound basis and to remove from business losses from unsound products, lost trade from dissatisfied customers and losses from lawsuits. Equally obviously, it is a peculiarly gross form of ingratitude. Modern industry and business have more of their essential roots in scientific research than in business sagacity. When business turns on the scientist who has offended it, it is usually turning on some one who has rendered it service in the past and who has put into its coffers many more dollars than the alleged offense of the scientist threatens to take from it, but business does not keep its lobbyists in Washington to reward scientists for services rendered but keeps them there to stop any activity in which the hypersensitive and myopic vision of the lobbyist may detect any immediate threat to the profit of the moment and regardless of the greater profit of the future.

In a speech before the Atlantic City meeting of the American Association for the Advancement of Science, David Dietz, science editor of the Scripps-Howard Newspapers, said:

> I do not believe that any scientist may feel that he has completed his work when he has finished a piece of work in the laboratory. It is likewise his duty to disseminate the new knowledge which he has discovered. This can be done only through the newspapers and hence the scientist to-day must be willing to cooperate with the newspaperman. He must be willing to submit to interviews by reputable newspapermen. . . . The scientist has every right to expect that he will be treated with fairness and

respect. He has every right to expect that his paper will be reported with accuracy and dignity, with no distortion of emphasis and with no unfair implications. . . . These are things which I know he will get at all times from members of the National Association of Science Writers.

In all this we concur. At the same time, we raise the question: After a fair account of the scientist's work has appeared in the newspapers, and business interests have started after the scientist's scalp, to what extent will the newspapers protect the scientist from the results of newspaper publicity which would not have followed from the presentation of the findings to scientific audiences or readers? Are they willing to publish the statement that a business interest is after the scientist because his fact-findings are more or less potentially inimical to profits, or will they follow the orders of their advertisers and leave the scientist to "take the rap" as a result of following Mr. Dietz's advice? There are at least two possible ways out of this dilemma.

One line of escape is for the scientist, at the first warning of impending trouble, to go to the business interests involved, point out that in the long run there is no conflict between science and business, that neither party is hostile to business or to the public health, that the objective of the scientist is to eliminate sources of sickness and death, to the ultimate benefit of business, and that unfriendly action can result only in injury to all parties concerned and to the public, and for the scientist to suggest cooperative action in the interest of both science and business. In the writer's experience, this line of conduct may meet with some degree of success.

The other line of escape, which is merely an extension of this, is for Mr. Dietz and his associates in the National Association of Science Writers to inaugurate a campaign in the press to educate business men as to the value of research intended to solve their problems, and to persuade them to look on newspaper publicity as Mr. Dietz looks at it. If the men who actually own and operate large business concerns can be educated to see their ultimate benefit, and to avoid the "jitters" when newspapers undertake their rôle in educating the public in regard to scientific findings, the newspapers will benefit by not having advertisers storming their business offices and threatening to withdraw advertising unless the papers suppress facts of a supposedly inimical nature. The public will benefit by an unimpeded flow of scientific facts through newspaper channels. Business will benefit by being freed from definite business handicaps by the earlier solution of the problems underlying those handicaps. Finally, the scientist will benefit by being freed from attacks which threaten his work, his welfare, his reputation and his job.

The few ideas presented here are in the nature of snapshots of the scientist in a few of his environmental conditions. Like snapshots in general, they aim at no complete or rounded portrayal of the scientist's life. As with snapshots, their destiny is to be glanced at and, perhaps, to leave a fleeting impression.

INFRA-MICROSCOPIC MAGNITUDES[1]

By Sir WILLIAM BRAGG

PRESIDENT OF THE ROYAL SOCIETY

A CURSORY glance over the research work described in the scientific publications of to-day shows that remarkable interest is concentrated on magnitudes which are too small to be examined in detail under the microscope and too large to be studied conveniently by x-ray methods. Such magnitudes are to be found in all lines of research, medical, industrial and purely scientific. Their behavior presents numerous problems of great interest, and also of considerable difficulty. Solutions are of pressing importance, because the want of knowledge is in all cases a considerable hindrance to progress. When in the course of our work we arrive at these magnitudes we realize that we are facing a key position.

The microscope makes it possible to detect objects as small as a few hundred Ångstrom units in diameter, but it is far from revealing the details of objects so small as this. There are other optical methods of detecting such magnitudes. Thus Langmuir has recently shown how the polarization effects of films no more than a few dozen A. U. can be made visible: but again this method does not supply a means of examining detail.

The x-rays in a sense go too far. Their wave-lengths are such that the crystalline arrangement of atoms and molecules can be measured with very great accuracy, but their field of view is too narrow to take in the details of larger structures. Thus there is a gap in the means of inquiry, and it is remarkable how consistently the particular deficiency has inconvenient results.

Magnitudes of this order occur for example in the metallurgical field. Their importance is more obvious now that the structures of metals and their alloys are better known. The x-ray methods determine with accuracy the details of the crystal structure of iron and its alloys, but such information is insufficient for a prediction of the behavior of a specimen of steel. As Smekal has observed, there are certain properties which are clearly connected with structure, and are "insensitive" to any treatments to which the steel has been submitted in its previous history. But there are other properties, to be described as "sensitive," which can be modified profoundly by treatment, such as tensile strength, plasticity and hardness as well as electrical and magnetic properties, and these are most important qualities in practice. Long ago the microscope showed the metal to be an assemblage of grains; and the conditions of the assemblage are clearly connected with the "sensitive" properties. But the exact details of the connection are difficult to investigate because they fall within the region in which direct illumination fails. Metallurgical theory hovers continually over the idea that a metal or an alloy contains minute groups of atoms or is even a compound of such groups which may be called crystallites since the arrangement of the atoms within each one is perfectly regular. The x-ray diffraction is regular and the lines of a "powder diagram" are clear and sharp. Thus Gough and Wood in their examination of the fatigue of metals due to the cyclic repetition—sometimes to millions of times—of an imposed stress, found that the visible grains gradually broke up to an extent which in any one experiment depended on the magnitude of the stress. Fracture in any one region occurred when

[1] From the Presidential Address given at the anniversary meeting of the Royal Society on November 30.

the break-up into crystallites was complete. It did not imply the disruption of atom from atom resulting in complete disarray, but merely a separation into minute crystals the magnitudes of which were arranged more or less closely about some average. This was shown by the form of the x-ray photograph. A definite stage had been reached in the break-up of the material. The existence of such an average would imply that the dimensions of the crystallite are in some way referable to numerical relations between the form or dimensions of the atoms of the metal: analogous to but far more complicated than the formation of the benzene ring of definite form and size from atoms of carbon each of which has tetrahedral qualities.

The discussion as to the specific existence, nature and effect of crystallites has been conducted with great eagerness, very much research on the mosaic structure of crystals in general has been undertaken, and several interesting theories have been put forward. At first theories were suggested which would have provided a super lattice, consisting of a regular arrangement of crystallites, even in the case of a pure metal. But this suggestion could not be maintained, as it evolved a second linear dimension out of a first. Buerger has suggested that the grain-like structure of a metal is due to conditions of growth, various crystalline processes meeting and joining together in irregular fashion during the formation of the whole mass. This however would lead to a casual formation, which does not seem to be in accord with metallurgical experiment. G. I. Taylor's ingenious theory of the hardening of a metal by working requires the existence of crystallites of some form. The whole question is still obscure, yet it is extremely important because the properties of metals and alloys depend to a large extent on the grain-like structure which they possess. Whether so-called "crystallites" are formed under some law governing their size or are merely accidental assemblages, they are a center of interest in the examination of metallic properties.

Similar conditions prevail in other cases where the behavior of materials is under consideration. In April of this year the International Association for the Testing of Materials met in London. It was attended by about 800 persons, many of whom had come from abroad. The subjects dealt with centered round the use of materials for every kind of engineering design and every kind of manufacture. Under cover of a conference on testing it drew together an imposing assemblage of men engaged in the constructive work of the world. In any constructive work the testing of the material must be a decisive factor in making the design and in building to it. The design of the test itself requires the most careful consideration, because it is always a compromise between what is possible and what is practicable. Knowledge of what is possible depends on scientific research and is related to scientific problems of the greatest interest and the most varied nature. Knowledge of what is practicable is related to other interests but is also founded to a large extent on scientific research. Thus the work of the conference was closely connected with pure scientific research, depending on results already obtained and suggesting numerous opportunities for the increase of knowledge.

It was remarkable that in the case of one material after another the discussion drew attention to the importance of grain-like structure, and showed that the "grain," if I may extend the word widely from its general use in metallurgy, was the object of attack. Thus in the vast variety of fibrous materials, the fiber corresponds to the metal grain, and its study is quite as interesting and important. In all colloidal problems the condition and properties of the minute particle are fundamental. In materials derived from

living organisms, the cell and its parts are the center of interest and of course somewhere in the region of which I am speaking are the outposts of life itself. Even in dielectrics and lubricants, the groupings of atoms and molecules determine the general behavior.

Moreover, a very considerable change in the use of materials for construction has come about in recent years in consequence of the fact that the gradual changes due to time have become really important. The so-called "creep" of materials is now one of the chief preoccupations of the engineer. Its new importance is due to two causes. In the first place the development of machinery has necessitated more perfect fitting, and less allowance for clearance than was at one time the case, as for example in modern turbines and internal combustion engines. In such fine adjustments a creep of one part in a thousand is a very serious matter. In the second place the working temperatures have been greatly increased, and creep is thereby encouraged. There is no doubt that in any specimen but a perfect crystal slow changes take place continuously. At every moment molecules are being helped over the barriers which have kept them from positions of greater equilibrium. In this way new crystallizations are set up, or older crystallizations extended. Strain may encourage transfer from one position to another. One might almost say that every portion of a solid is a liquid for a certain fraction of its time, and that the atoms in that portion are capable of a movement which is restricted and guided by the stabilizing action of their surroundings.

The laws which govern these movements are very complicated, and detailed knowledge is scanty though badly wanted. Thus according to Dr. Bailey, a pioneer in these matters, the addition of 1 per cent. chromium to a 0.5 per cent. molybdenum steel increases its initial resistance to creep below a certain temperature and lessens it above. It is probable that the addition of chromium atoms locks the grain structure so long as they stay where they are: but heat facilitates their moving, all the more readily because the complicated alloy has the looser structure. Once they have moved the material would be better without them. But such a rough explanation would be well set aside for a detailed knowledge of the processes involved. Here are very interesting problems of physics and chemistry.

The careful examination of a visible cellulose fiber shows, it is said by some, that it is built up of lesser fibers, fibrillae or fibrils, which again consist of ellipsoidal objects of dimensions roughly 1.5 and 1.1 μ. Each such object may contain many millions of cellulose chains, but very little is known of the structure of the contents or of the sheath that encloses them and seems to be the source of their characteristic influence. Chemical analysis and x-ray examination give a satisfactory picture of the cellulose chain-like molecule, and some information also of the details of the molecular assemblages. But information is wanted respecting the larger groups and the fibril formation on which the fiber properties obviously depend. If the fiber belongs to a living organism, change with time may be synonymous with growth. If the fiber is an element of some material in use, it is still subject to change which may seriously affect its quality.

Change may be external or internal. The slow rearrangements of recrystallization or devitrification are due to internal forces: but surface changes due to reactions with surrounding atoms such as corrosive or hydration may also affect behavior. Naturally such surface changes are the more important the smaller the particle of the substance, as the colloid chemist points out. Thus, for example, it is a much discussed question as to how clay holds the water that is associated

with it. The x-ray analysis supplies a very reasonable picture of the clay crystal; the positions of the atoms of oxygen, silicon, aluminium, magnesium, iron and the rest are known with considerable accuracy. But the remarkable properties of clay are dependent on the behavior of the larger flake-like assemblages of colloidal dimensions, which lie between the direct observation of the x-ray methods and those of the microscope.

In dielectrics the slow changes of time bring about rearrangements, hastened by the electrical tensions to which the material is subjected. The electrical forces look for the weakest point for a breakthrough, just as a stress discovers the weakest point of a chain or any member of a structure. Changes are therefore important. One would wish that a structure was like the "Deacon's shay," which was so designed that every part was as strong as every other so that when the shay came to its end, it became a heap of dust upon the road. Unfortunately that is not the case with any material in use: and whatever its structure an equal balancing is apt to be destroyed by changes in its grain-like condition.

Perhaps the structure of the huge protein molecules may suggest a way of closing the gap in our knowledge and our means of inquiry. It is a very striking fact that their magnitudes tend definitely to group themselves about certain values, which moreover are simply related to one another. They are not mere groups of atoms thrown together without design. Their definite formation implies obedience to rules which must be in force at the beginning of the assembling, and are in force until an unavoidable result is reached. This would mean, as indeed a vast number of observations already imply, that the junction of carbon atoms is governed by strict geometrical laws of distance and orientation. It has indeed been pointed out by Dr. Wrinch and others that the long chains consisting of two carbons and one nitrogen in regular succession can be formed, under the guidance of the rules mentioned, into space-enclosing sheets presenting an external appearance of linked hexagons, and the number of sizes to which these assemblages can attain is limited. Possibly we have here an example of a form of procedure from the groupings of a few atoms to the larger assemblages of thousands, the process depending on a certain obedience to laws of building which have been shown to hold in the simpler case. We are encouraged to hope that this may be so, by the unexpected strictness and definiteness of the building rules in the cases which fall within the scope of the x-ray methods.

The constitution of the solid body is being examined now as it has never been possible to examine it before. We are not surprised that it is found to possess a grain-like structure, nor that this structure is of first-rate importance. It is not only of interest from the purely scientific point of view, but it turns out to be of fundamental importance to all the constructive work of industry and to all the examinations of living constructions within the domain of biology. In the effort to know its details and to understand their significance a host of interesting scientific inquiries make their appearance, so that industry and science more than ever play into each other's hands. It is certainly to be expected that from these tempting labors there will result much improvement of natural knowledge.

HUMAN RELATIONS TO NORTHWEST GEOLOGY

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To inquiring minds a journey through the Northwest affords pleasure in direct proportion to the knowledge the travelers possess about the origin and effects of both common and unusual earth features. How often tourists wish for explanations! To the uninitiated all mountains look about alike, glaciers are bigger but hardly more exciting than ice cubes from the refrigerator, communities packed with romantic history, whose very location depends on nature, are only remembered because of a nail that forced a tire change.

The foundation of a continent consists of hard resistant rocks once buried deeply beneath the earth's surface and changed by intense heat and pressure into granite, gneiss, schist and argillite. Around "islands" of ancient rock in the Northwest nature deposited younger and generally softer strata, uniting all to form part of North America. During the geologic past broad oceans rolled over wide areas now land, mighty mountains were uplifted and later reduced to low plains, volcanic activity deluged the land with molten rock and ash, coal beds formed in the deltas of forgotten rivers, the climate slowly but profoundly changed, ore bodies were formed and soil accumulated. In these and other ways nature prepared the Northwest for man's occupancy.

Mountains display distinctive characteristics, depending on their origin. Hence mountains have different effects on man when formed in different ways. Some mountainous areas, like southwestern Montana and central Idaho, result mostly from intrusions of molten rock, now solidified to form granite and similar rocks. Since metal deposits may come from such intrusions many mines exist in areas of granite exposed in southeastern Montana, central Idaho and northeast Oregon. Many times the metallic ores occur in remote, rugged regions difficult and expensive to reach by rail or highway. Men have built scores of mining towns in narrow mountain canyons like Burke, Idaho, or in high frosty altitudes like Butte, where only a few cowboys or lumbermen would live except for the veins of ore. Most mining towns have a short life and dozens of ghost cities mark the sites of busy mining operations in the past. The fact that mines at Butte and in the Coeur d'Alene region of northern Idaho have operated for over fifty years merely forms the exception that proves the rule of a short life for most mining communities.

Volcanic eruptions have covered a major part of the earth's surface in the Northwest. The Cascade mountains in Oregon and the southern half of the same range in Washington have been almost wholly built up by thousands of lava flows superimposed on each other like a long heap of griddle cakes. At intervals certain vents provided exceptional quantities of lava and cinders. Here huge cones developed that tower above the general plateau-like summit of the Cascades. Capped in glistening white, these snow sentinels, Rainier, Adams, Shasta, Hood, Baker and other volcanic peaks, form a major scenic attraction.

Between the Cascades and the northern Rockies lies one of the greatest lava fields of the world. Here lava welled

out from long rents in the surface and buried an area of 200,000 square miles. In places successive flows aggregate nearly a mile thick. The Snake River in its canyon, south of Lewiston, Idaho, has cut through over 4,000 feet of lava and has incised itself more than 1,000 feet in the underlying granite. The Snake River Canyon attains a depth of over 6,000 feet, the deepest in North America. Unadvertised and seldom visited, since it is off the main tourist routes, this mighty gorge of the Snake River offers one of the most spectacular river trips in the world. During high water in May a sturdy flat-bottomed motor boat can climb the rapids and reach Johnson's Bar, 100 miles south of Lewiston, among the mountains called "The Seven Devils." The canyon of the Salmon River, a major tributary from the east, has a depth of over 5,000 feet. The Salmon is called "The River of No Return," since no boat has yet struggled up its swift rapids. While lava flows probably began to cover the Columbia Plateau several million years ago, in southern Idaho and Oregon, eruptions ceased perhaps only a thousand years ago. The Craters of the Moon, scene of possibly the last volcanic activity in Idaho, forms a National Monument, containing spatter cones, tree molds, cinder cones, ice caves and other phenomena.

Centuries often elapsed between successive lava flows. Soil formed and trees grew. Then renewed floods of lava devastated the land knocking down the forests and burying some trees without completely burning them. Such logs have been often slowly replaced by quartz carried by ground water and thereby petrified. Thousands of such petrified logs have been found, including ginkgo, redwood, walnut, elm and many other hardwoods now extinct in the Northwest because of climatic changes caused by the creation of the Cascade Mountains. The largest collection of fossil trees occurs near Vantage on the Columbia River near Ellensburg, where over 2,000 specimens have been located. Some of the associated lava is of the "pillow" type, solidified in oval masses, probably when the lava flowed into some body of water that possibly may have kept rafts of logs from burning. On exposure to air silicified wood loses some combined water, becomes much harder, forming chert or flint. Indians first discovered the petrified Vantage forest and quarried the hardened outcrops of logs for arrowheads and other utensils. How strange, that prehistoric wood, replaced by stone, should serve as raw material for weapons!

Mountains resulting from vulcanism tend to form piles and groups of peaks rather than long ridges. Thus the Judith, Moccasin, Crazy and Little Rocky mountains of Montana that rise like islands from the general level of the Great Plains, all results from intrusions of molten rock. The Highwood and Bearpaw Mountains form similar "island-like" groups, but resulted mainly from volcanic eruptions. All these Montana mountains rise high enough to have sufficient rain to support coniferous forests and thereby offer cool, pleasant retreats from the summer dust and heat of the grass-covered plains round about.

The only active volcano in the United States is Lassen Peak, 10,453 feet high, in the Cascade Mountains of northern California. This volcano had scores of eruptions about 20 years ago, that threw out cinders and ashes and one lava flow. Heated explosive material melted the snow on the mountain side in May, 1915, causing a flood, accompanied by blasts of hot gases, that knocked down windrows of huge trees and devastated ranches in the valleys of Hat and Lost Creeks. The débris left by this flood and great hot rocks hurled long distances by the explosions form a spectacular sight. Hot springs and steam vents at Lassen Volcanic National Park are evidence of some

source of heat that may again break forth. Indians have legends about eruptions of Mount St. Helens, in Washington, a century ago and earlier eruptions of Mount Adams and Mount Rainier. The Northwest may again have some volcanic activity, but it seems unlikely that eruptions will come severe enough to damage much property.

Crater Lake occupies the caldera (enormous crater) of an extinct volcano once comparable in size to Mount Shasta. Either by collapse or more likely by explosion the peak was destroyed, and a vivid blue circular lake 2,000 feet deep and six miles across lies within the former body of the volcano. Crater Lake is the deepest lake in America, so deep that it never freezes over, although lying in a high, cold part of the Cascades. A launch trip around this liquid sapphire gem, set amid red and yellow cliffs partly shrouded with green conifers, forms a never-to-be-forgotten sight.

The system of National Parks in the Northwest began with the creation of Yellowstone Park in 1872. The hot springs, geysers, waterfalls and animal life unite to make Yellowstone the best known of all parks in America. A buried batholith (large intrusion of lava) serves as the source of heat for the steam vents and hot springs. Ordinary rain-water drains from surrounding hills into basins underlain by hot rock, which heats the percolating water. The Mammoth Hot Springs deposit lime called calcareous tufa or travertine and have built up beautiful terraces. The lime comes from dissolved limestone that was once shells on the bottom of the sea. The lime deposition is aided by tiny plants, diatoms, living in the hot pools. The diatoms also color the water and travertine deposits yellow, brown and green. A geyser results from surface water, heated underground, draining from several sources into a tube from which steam causes a periodic and violent eruption.

Mountains formed by folding, like the Little Belt and Big Snowy mountains of central Montana, form a hundred-mile-long east-west barrier that only two highways cross through Neihart and Judith Gap. Mountains formed by great breaks or faults of the earth's crust may rise very steeply from adjacent lowlands like the Lewis Range, that forms the east front in Glacier National Park. Here an "overthrust" fault has pushed hard, ancient strata for twenty-five miles across younger, soft shales. Stream and glacial erosion have combined to dissect the Lewis and Livingston Ranges of Glacier Park into rugged spectacular scenery. In the Gallatin Valley and near Helena earthquakes in recent years resulted from sudden movements along faults. Beautiful lakes, waterfalls and vari-colored cliffs remain as mute evidence of profound uplift and erosion in the past. The Big Belt, Bridger, Mission, Bitterroot and most other ranges of Montana trend north-south or northwest to southeast. Since the main railroad and travel routes go east and west the few valleys and passes that carry these routes become major factors in determining the location of both cities and rural populations. Thus Missoula stands at the junction of the Clark Fork and Bitterroot Valleys, and Spokane lies at the west end of the chief through pass railroad routes in the northern Rockies. On the other hand, the growth of Walla Walla and Lewiston has been hindered by high, difficult mountains in central Idaho, across which no railroad or good automobile road extends.

The glacial period has affected man significantly in the Northwest. Glaciers covered the whole of northern Washington and capped the mountains everywhere. Floods of melt water were factors of importance far beyond the edge of the ice sheets. A thick lobe of ice filled the Puget Sound Lowland between the Cascade Mountains and the Coast

Ranges, to a distance of several miles south of Olympia. The blocking of Puget Sound by this glacier created a lake of melt water in the front of the ice that overflowed into Grays Harbor. Silt deposited in this lake now forms rich farm land around Chehalis and Centralia. The Skagit, Puyallup and other rivers that enter Puget Sound have built deltas and fertile flood plains of glacial silt and other fine débris. Such areas constitute the best farm land in western Washington and raises berries, bulbs, vegetables and other crops. The well-drained uplands, in contrast with the rich lowlands, have suffered from the leaching by the heavy rainfall of the West Coast that removed much soluble plant food. Such areas in Oregon and Washington are best adapted to dairying and forest growth. Puget Sound, like the Great Lakes, was created by glacial erosion. Previous to the Ice Age what might be called the "Puget River" flowed across a lowland underlain by weak rocks to the Pacific by way of the Strait of Juan de Fuca. Thick glacial ice eroded the valley of "Puget River" and its tributaries below sea-level and carried the débris away. When the glacier melted, rock material contained in the ice was dropped everywhere around the region. The hills at Seattle resulted from such glacial deposits. Elsewhere glacial dams created lakes, some of which, like Lake Whatcom, Lake Washington and American Lake, are many miles long. With the disappearance of glacier ice, ocean water invaded the lowland forming Puget Sound, probably aided somewhat by local sinking of the coast. The hundreds of islands and irregular peninsulas of Puget Sound mostly occupy the former divides of the drowned river valleys.

Glaciation profoundly affected large areas in eastern Washington not even covered by ice. This happened because a thick ice lobe, coming from Canada through the Okanogan Valley, completely blocked the Columbia Valley, here nearly 2,000 feet deep, and moved southward across the Waterville Plateau for thirty miles before melting. The glacier knocked off great blocks of basalt lava from the cliffs above the Columbia and carried these erratics (locally called haystack rocks) many miles south. Some of the "haystacks" rank with the biggest glacial boulders known, weigh thousands of tons and exceed in size a large barn and house together. The blocking of the Columbia River by the glacier at the mouth of the Okanogan Valley caused a long lake to fill the Columbia Valley. This lake, called glacial Lake Nespelen, and other marginal lakes in front of the ice rose until they overtopped the divide south of the Columbia and Spokane rivers and flowed swiftly across lots down the slope of the Columbia Plateau towards the Snake River and lower Columbia Basin. This glacial melt water was joined by enormous floods released by breaking of ice dams that held temporary lakes in western Montana and elsewhere. The resulting floods washed away all surface soil in channels, some of which are ten to twenty miles wide, and locally wore deep canyons into the underlying lava. The resulting interlacing channels of rock are called "scablands" after the bare lava named "scab rock." Many long, narrow lakes now occupy the deeper basins torn out in the channels by the tumultuous flood.

The most spectacular of all the scabland channels is the Grand Coulee. This extends for 50 miles from the Columbia River to the Quincy Basin. The upper Coulee has a length of 30 miles, a width of 1 to 5 miles and was cut 900 feet deep. The lower Coulee begins at "Dry Falls" and extends 20 miles to Soap Lake. "Dry Falls" is 420 feet high and over 3 miles wide. When in operation this falls was incomparably grander than Niagara. According to J Harlen Bretz, of the University of Chicago, the upper Grand

Coulee was eroded by the headward retreat of a giant cateract clear to the Columbia Valley. At Steamboat Rock this extinct cataract was 900 feet high and over 5 miles wide and was named by Bretz "Steamboat Falls." Nothing comparable to such a giant waterfall is known elsewhere on earth. After its formation Grand Coulee carried the glacial melt water until the ice dam at the mouth of the Okanogan disappeared and the Columbia River resumed its course, leaving the floor of Grand Coulee 600 feet above the Columbia. During the ice age the Columbia Basin, into which Grand Coulee drained, was deeply buried under gravel and silt. Over 1,000,000 acres of Columbia Basin land is highly fertile but desert soil without adequate water for irrigation. In 1933 the government began to construct a dam across the Columbia River at the head of Grand Coulee intended for both power and irrigation. When completed this dam will be 450 feet high and 4,200 feet long and will contain three times as much concrete as the Boulder Dam. The dam will create a lake nearly to the Canadian line resembling that of glacial times. Water will be pumped from the lake to the floor of Grand Coulee to water the Columbia Basin desert.

In connection with the floods of glacial melt water, enormous gravel terraces filled the Spokane Valley, even blocking tributary valleys with gravel bars back of which lakes developed like Newman Lake and Liberty Lake. Along the Columbia and Snake rivers gravel deposits, hundreds of feet thick, were formed during the same time.

After the ice age, glaciers lingered in the mountains. As these mountain glaciers wasted away the valleys disclosed evidence of profound ice erosion, sharp ridges had disappeared, the valley floor had a broad U shape, studded with ponds and lakes. At the head of the valley a vast amphitheater or cirque with precipitous walls had developed as the result of glacial headward erosion. The rugged scenery of Glacier Park, the Grand Tetons and the Cascades resulted from glacial action. Everywhere the existing glaciers are waning. Several in Glacier Park will not outlast the century. Among the 48 states Mt. Rainier has the longest glacier, the Nisqually, 6 miles in length, and the largest ice river, the Emmons glacier. In all 24 glaciers descend Mt. Rainier, well into the Douglas fir forests at 4,000 feet elevation. Yet the Nisqually glacier has melted back over half a mile in fifty years and will ultimately shrink to a fraction of its present length. A lovely feature of Mt. Rainier consists of flower-decked mountain meadows surrounding the white peak of about 5,000 to 7,000 feet elevation. The headward erosion of glaciers sometimes lowered the divides between two valleys. Such routes were followed first by Indian trails, then by highways and railroads. The Snoqualmie, Cascade, Stevens, Naches and other passes in the Cascade Mountains resulted in large measure from glacier erosion. The same is true of many passes in the Rocky Mountains.

Geologically the Columbia has the characteristics of youth—narrow gorges, rapids and lakes. Some river may have flowed in parts of the Columbia valley for millions of years, but since the stream flows through mountains and plateaus where the work has just begun of carrying to the sea all this material, geologists consider the river still in youth. One might say that a river has feminine characteristics in that it is no older than it looks! Most rivers have their greatest drop near their head waters where the stream is small, but the Columbia, after attaining a large volume, drops 1,000 feet in 420 miles while crossing the state of Washington from Northport on the Canadian border to Wallula close to the Oregon line. Some of the rapids result

when the river in steadily eroding its bed reaches lava flows or other resistant rocks. In other cases, deposits, either from glaciers themselves or from the floods that resulted from melting ice, filled up an old valley and made the river change its course. Later the stream, cutting downward in this new location, might come in contact with a buried ledge of resistant rock, like granite, in which it might erode a narrow gorge. This happened on the Spokane River at Post Falls, Long Lake and Little Falls and determined the large power sites there. Engineers of the U. S. War Department state that by the construction of eight great dams in Washington and Oregon on the Columbia over 11,000,000 horse power could be developed. This is over one sixth of all the water power available in the United States. When this power finds use, another industrial area, equivalent to all New England, will supply manufactures to the Orient and other parts of the earth. Another glacial drainage change formed the Great Falls on the Missouri, where that river descends 512 feet in 12 miles, forming one of the greatest power sites in America.

In the geologic past lakes occupied depressions east of the Cascades. Mud slowly filled the lakes, and sometimes logs and leaves of trees and bodies of dead animals were added. The beds of clay and sand deposited in these long extinct lakes to-day constitute fossil hunting grounds that have furnished specimens to museums all over Europe and America. These lake beds have supplied skeletons of the three-toed horse, ancestral camel, primitive rhinoceros and scores of other animal species besides the leaves or wood from hundreds of different plant species.

The finding of underground water in eastern states of the Union seldom proves difficult, but in arid parts of the Northwest water makes life. Fortunately the mountains enjoy abundant rain and fill with water both surface streams and underground reservoirs. Sometimes valleys adjacent to the mountains contain fertile, easily irrigated benches, giving ideal conditions for growing alfalfa, sugar beets, potatoes, hops and fruit, like the Yakima Valley in Washington.

Beds of gravel or other pervious material may serve as conduits to carry water underground from the mountains into adjoining lowlands. Where some impervious stratum caps the water-bearing rock, the water may have enough head to form an artesian well when penetrated by a drill. In eastern Montana, near Klamath Falls, Oregon, and other places, artesian wells supply irrigation water. In regions with few springs, artesian water had attractions for settlers, and the drilling of artesian wells aided the growth of towns, for example, Pullman and Palouse, Washington. A spring or other source of drinking water provided a common excuse for the location of a trading center. Sometimes even a considerable village might haul drinking water from a distant source. Then when some "homesteader" dug a successful well, the town might move to the water supply. This happened at Waterville, Washington, and determined the name of that small city.

Sometimes a canyon cuts through a large water-bearing bed and giant springs gush from the canyon walls. This determines the "Thousand Springs" in the Snake River Canyon. Here a single spring runs a fair-sized electric power plant. One of the biggest springs in the Union exists at Giant Springs, close to the Missouri River at Great Falls. A small part of the flow of Big Springs supplies Lewistown, Montana, with all its municipal supply.

Nature has formed caves in several ways in the Northwest. Solution caverns may occur wherever limestone outcrops. Here percolating ground water slowly dissolved the limestone along the cracks

or joints and bedding planes until considerable caverns resulted. A change in flow of ground water may drain a cave and cause indripping water to evaporate and deposit lime in the form of hanging stalactites and other beautiful, much admired forms. Examples include the Lewis and Clark Cavern in Montana and the Oregon Cave, southwest of Grant's Pass, Oregon. Some caves are phenomena of lava flows. Molten rock may solidify around big gas bubbles and leave a cave. Lava hardens around large tree trunks, thereby forming a cave. Lava tubes form the largest caves in volcanic regions. Here lava cooled on both top and sides of a lava flow and when the molten lava under the surface flowed away a cave was left, sometimes traceable for miles. Such caves are common near Bend and the Modoc Lava Beds.

An interesting phenomenon of some caves in regions of cold winters is the formation of ice during summer months. Several ice caverns occur in limestone in the Judith and Big Snowy Mountains of central Montana. Other ice caverns exist in lava caves, like Shoshone Cavern in southern Idaho and in eastern Oregon. It is generally accepted that heavy freezing cold air of winter descends into caves, and chills the rock below the freezing point of water. In the spring and summer in-trickling water freezes from this source of "cold." Even when the supply of "cold" is exhausted the ice melts very slowly, since the sun can not reach the ice in the cave and the air can conduct little heat into the cavern.

Winds and currents make effective geologic agents along exposed coasts by depositing barrier beaches of sand across the mouths of inlets, as at Gray's Harbor and Willapa Bay. These sandy barrier beaches form delightful summer resorts. The protected waters behind the beaches make favored places for growing oysters and clams.

East of the Cascades areas of sand dunes occur in the Columbia Basin desert and along the Columbia River, where sand deposited by spring floods may be blown away from the stream after drying out in late summer. For ages dust blown from the desert has been deposited to leeward and retained in the rainier, well-grassed Palouse region. This dust, called loess, mixed with abundant humus from decaying grass, forms a rich, deep, black soil of exceptional fertility, well adapted to grow wheat. It seems as though nature provided strong winds to transport soil from regions too dry for farming into areas of rainfall sufficient to favor crops.

POTTERY YARDSTICK AT MONTE ALBAN

By CARL C. DAUTERMAN

THE NEWARK MUSEUM

"UNEXPLORED." This challenging word has almost disappeared from the geographical maps of to-day, but it would occur repeatedly on any map of Mexico which attempted to show only those areas known to archeology. The rest of the country would look like a group of scattered islands. Difficulties in climate, transportation and expense have conspired to keep field workers out of large areas, and with the exception of the Valley of Mexico and Yucatan, archeological investigations in Mexico have been largely sporadic. In the light of recent finds at Monte Alban, this paper is an attempt to search the cultural islands of Mexico for likely points at which to throw bridges to link the "archipelago" together.

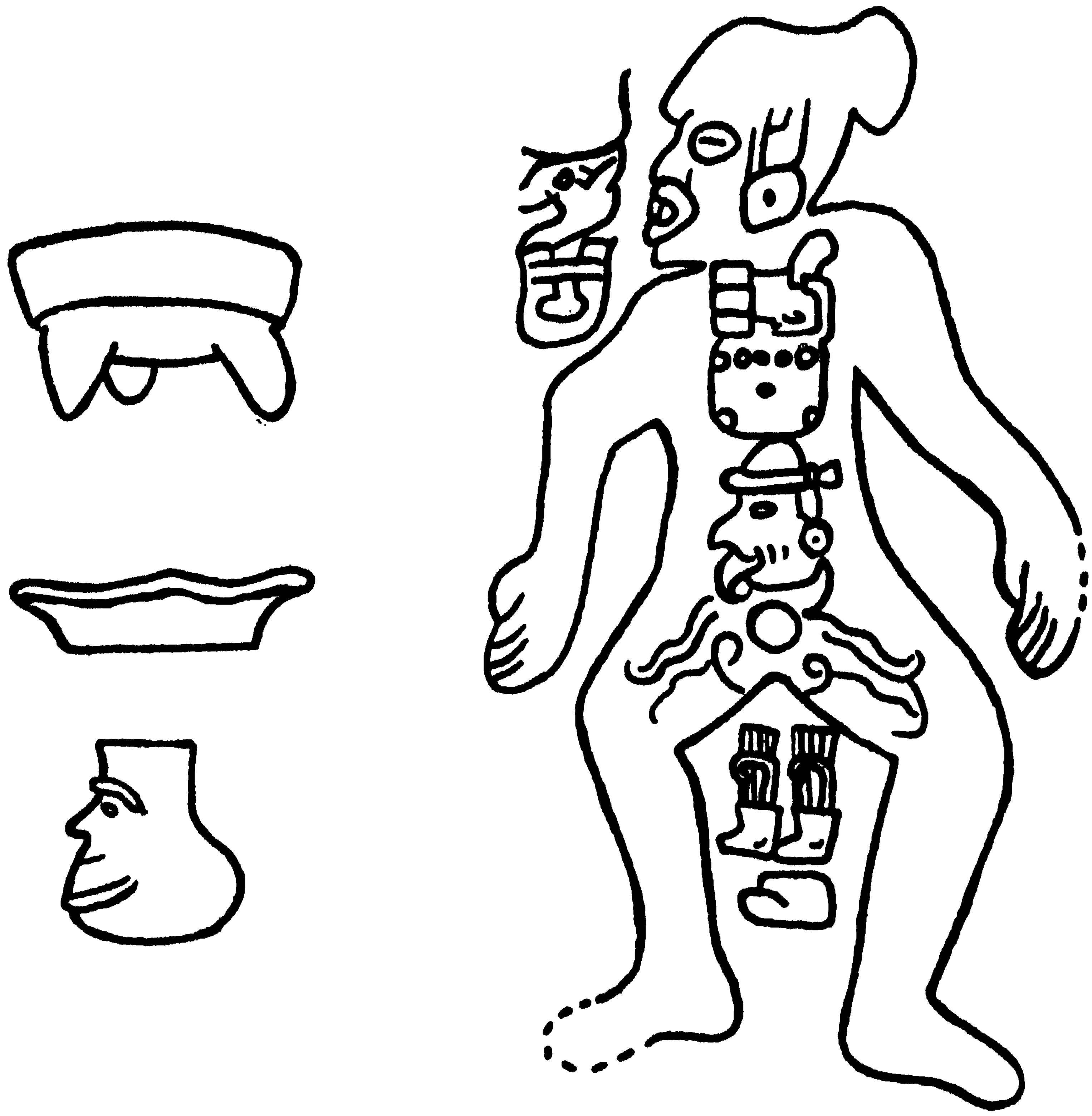
When speaking of the early civilizations of Mexico most of us are inclined to think in terms of the Aztecs and the Maya. The reason for this is that of all the people living in Mexico in the early sixteenth century, these two most aroused the wonder of their Spanish conquerors for the high development of their ways of living. The early descriptions of these people provide us with merely an introduction to the complicated Indian life of Mexico.

Because the Aztecs and the Maya could boast a system of writing, a calendar and an advanced knowledge of astronomy and the arts, the world has become curious to know something of the mysterious past out of which these things grew. This has sent students along many different paths. Some have tried to decipher the native manuscripts, which are few and puzzling. Others are tackling the languages, believing that peoples now living far apart who use the same groupings of sounds for conveying the same ideas may once have been close together geographically and in their manners and customs. Still others are looking for comparisons in the physical types, the arts and architecture, even in the legends and superstitions, to trace the knotted lines of Mexico's development.

In all this delving there are certain evidences of peoples who were given slight mention by the Spaniards or whose names had disappeared from memory before the white men came. The inhabitants of Monte Alban represent two of these little known groups. They were called the Zapotecs and the Mixtecs.

At the completion of the fifth season's work in 1936, there was not the slightest doubt that Monte Alban was built and rebuilt by the Zapotecs over a long period of time. It is still yielding a kind of funerary urn, which always has been attributed to the Zapotecs because found only in the area inhabited by them, and in addition a preponderance of pottery with the unmistakable stamp of Zapotecan craftsmen. What is even more important is that an evolution of this pottery can be traced through many variations of form and decoration which represent successive periods of time and their attendant social changes.

The modern archeologist is characterized by his willingness to believe in the things he finds in the ground, as against the old-time antiquarian who reconstructed the story of the past out of books and a colorful imagination. The archeologist has to be constantly on his guard, especially in Mexico, where so much of the country's history has been gleaned from the Aztecs that it is quite naturally colored by Aztec ideas and prejudices. Even so, native writings and early chronicles can afford good "leads,"



THE OLDEST POTTERY AND THE OLDEST SCULPTURE AT MONTE ALBAN.
MUCH DEPENDS ON THE RELATIONSHIP BETWEEN THEM.

and the field man is not unhappy if he can "harness dirt to documents."

The Zapotecs did not receive any such mention as the Conquistadores accorded the Aztecs and the Maya. Of their own writings very little remains. Therefore the excavations at Monte Alban provide a good example of the method by which "dirt archeology" is gradually piecing together the pageant of man's development in the Americas.

The history of an archeological site is not expressed adequately in its magnitude, its temples or in the wealth of its tombs. Curiously, one must rely upon the humblest remains of all to penetrate into the unwritten story of an abandoned city. These are the pieces of pottery, mostly broken, which the inhabitants used in their daily lives or buried with their dead. Dr. George C. Vaillant has shown by word and deed in the Southwest and Central America that this is ideal material for archeological purposes. By its nature it can withstand conditions of heat and moisture which would destroy objects of wood and cloth. Having little value and being difficult to transport, it has survived generations of treasure seekers. Intended mainly for everyday use, it thereby escaped destruction at the hands of the Conquistadores, which was the fate of so much religious art. And although much of it has been reduced to fragments, a large proportion of all that was ever made has endured in recognizable form. For these reasons and because it was a medium which could respond to the fleeting fashions of its day more readily than architecture or sculpture, which were laboriously produced, pottery has preserved for those who will

read it the most complete record of the time and cultural phases of the peoples of Middle America.

Applying the pottery yardstick to Monte Alban, we find it a far cry from the orderly accumulations in the dump heaps of our American Southwest, where remains are found in the relative order in which they were laid down: the older layers at the bottom and the more recent at the top. For at Monte Alban there is hardly a cubic yard of undisturbed earth except under the foundations of the oldest temples. It is an example of a mountain remodeled by the hand of man.

Imagine, then, the difficulties involved in sorting into a chronological order the scattered fragments of pottery found in earth that has been carried from one section and dumped at another, there to consolidate with refuse of the moment and perhaps earth from other parts also containing refuse old and new. While an expert could conceivably trace a sequential relationship through such a welter of pottery purely on the logical passing of one design or style into another, it would not satisfy modern archeology, which asks for stratigraphical records so that other investigators may know the exact conditions of the soil, the level and the associations of every single piece as found.

It may be hard to see how even such detailed information could be very useful in straightening out the tangled thread of developments at Monte Alban, but fortunately the very force which was responsible for the thorough jumbling of Monte Alban's pottery also provides an excellent key to the confusion. We refer to the building of temples and their pyramid platforms. For here, as throughout Middle America, temples and pyramids grew by a process of accretion in which existing buildings were sealed or demolished, to provide a foundation for ever newer and larger ones. It was this prodigious effort, probably a form of religious penance, which caused large areas of this Zapotec center to be torn up and removed for landscaping or for filling out the bulk of new buildings. In this way the strata of earth were scattered and mixed, but at the same time, *within the mounds,* there were being deposited successive layers of fill, which remained untouched thereafter because built over. And fortunately, each level was separated from the others by a band of stucco or other masonry spread across its top to serve as a floor for the new building above. Thus a section through a mound resembles a book in which one paragraph containing several ideas is separated from another by proper spacing, so that while there may be some repetition of the contents, the two paragraphs stand clearly apart. And as in each succeeding paragraph a new thought is introduced, so in each higher layer of a mound some style of pottery which was non-existent when the other layers were formed makes its appearance.

It is obvious that each layer is likely to contain some of the pottery which was in common use at the time of building, along with whatever older forms existed in the earth that was dug up to be used as fill. Thus the old forms may be scattered through the entire mound, while new forms as they appear serve as an index to the changing standards, indicating by their position within the mound whether the trend is toward improvement or decadence. Whenever a new form appears it is looked for in the layers below. Naturally, the bottom-most of these to yield it is identified as roughly contemporaneous with the first appearance.

At Monte Alban five distinct ceramic epochs are recognized. They are distinguished by differences of form, color, polish, ornamentation, etc. In going down into a mound, therefore, one might find all types represented at the top, but as the shaft deepens the newer types peter out and disappear, leaving only the very oldest in actual contact with the undisturbed ground. At Monte Alban

this is frequently pure Type 1, proving that the building in which it was found was begun during the first cultural epoch.

Tombs, also, form an important source of pottery and provide a check against the stratigraphy of the mounds. In fact, tombs mark divisions of epochs more clearly than the layers of the mounds, for their contents are limited to things in vogue at the time of burial. Often they are the only source of unbroken vessels, rewarding and encouraging the archeologist who has vainly tried to fit together a hundred pieces for the pleasure of seeing a pot in its entirety. But a tomb has its greatest value, no matter how humble its contents, when its relation with another tomb can be traced stratigraphically. It's the position that counts.

Thus of two adjoining tombs, the lower should be the older, and if both contain pottery there should be the same relationship among the forms as exists in the strata of the mounds. At Monte Alban the series is now complete. There are surface tombs of epoch 5 overlying tombs of epoch 4, 4 over 3, 3 over 2 and 2 over 1. Comparatively few tombs of epoch 1 have been found because, being the oldest, they are naturally the deepest. But the "system" works. It is in agreement with the strata of the mounds after being checked repeatedly. It provides a kind of clock for registering the duration of man's occupancy of the site. And it hints at important cultural changes, some imported from distant places, which may also be reflected in the architecture, religion and the economic conditions of the people.

We have said that there were five pottery epochs at Monte Alban. The first has been called "Archaic Zapotec";[1] the second, classic Zapotec; the third and fourth, Zapotec with influences from Teotihuacan and the Maya area. The fifth is completely different and indicates that the city was given over to people of another culture. These divisions, although still tentative, provide a useful outline or foundation upon which other developments can be fitted into their proper sequence. By examining these pottery epochs one by one we can get something of the trend of events at Monte Alban.

First Epoch

The very first pottery epoch is perhaps the most challenging, for it presents a high degree of technical skill. Most of this ware is metallic-looking, gray or black, with a high polish and incised decoration. It is so well made, so skilfully finished, that it surely represents long years of development. But where? Certainly not at Monte Alban, for there is no trace of anything earlier or cruder in all the oldest deposits. This forces us to admit that the people who first inhabited Monte Alban brought with them a well-developed craftsmanship.

Dr. Alfonso Caso, director of the excavations at Monte Alban, sees in this oldest ware certain resemblances to a style of stone carving which Batres[2] named the "Dancers" type, referring to the dance-like attitudes in which some of the figures are depicted. Both the sculptures and the decorations on the pottery consist of simple incised lines, suggesting a single method of approach. But an even more important similarity exists in the treatment of line, which is free and sinuous. There are many examples of Type I pottery in which the hands and feet and heads of monkeys are represented in the same style as the Dancers carvings. This same freedom is not seen again in any of the later pottery or in the rest of the sculptures at Monte Alban, for its place is taken, as elsewhere in Central America, by the rigid conventionalism which clamped down upon carving, drawing and painting during the more advanced stages of culture.

[1] Alfonso Caso, *Instituto Panamericano de Geografía e Historia* Pub. No. 16, Mexico, 1935.

[2] Leopoldo Batres, "Explorations of Monte Alban," Mexico, 1902.

A great many points of interest bear upon the relationship of Type I pottery and the Dancers carvings, especially if these be contemporaneous. There has been some criticism against the age of these carvings, because so many of them have been re-used in structures of late date, as revealed by the pottery types enclosed beneath the masonry. However, in the 1934–35 season, several of these sculptures were found *in situ* in a hidden pyramid beneath the temple of the Dancers. As this pyramid contained earth almost free from pottery it was believed to be one of the structures of the first epoch at Monte Alban.

These two things, then, the pottery of Type I and the Dancers carvings, appear to stand together in age and in style. Where do they fit into the scheme of things as a whole for Mexico and Central America? That can not be answered at this stage, for the sculpture is a part of that puzzling complex of negroid and bearded figures, "tiger faces" and "baby faces" of which Vaillant, Saville[3] and others have written.

"How far primitive sculpture as a guide to race can be trusted we do not know, but it is apparent that in some of the higher Middle American cultures there was a recognition of the physical characteristics of several peoples besides the Mayas and the Nahuas."[3a]

The peculiar carvings of top-knotted human heads, product of an unknown people in the Mexican State of Guerrero, have a strong resemblance to these early sculptures of Monte Alban. Will future work in stratigraphy prove them related?

Dr. Caso sees in the Dancers an affinity with certain carvings of Salvador, and this fits in with the idea that Central America rather than Mexico may have been the scene of the invention of agriculture and the birth of civilization in the New World. This awaits proof, but even if the investigator fails to find traces of the beginnings of the arts in Central America, he will enrich the world's knowledge of the strange commerce and the cultural influences which flowed between the centers of population in North and South America. There are as yet no final answers to the separate problems of who were the first people of the New World to develop agriculture and who were the originators of the specialized arts.

Second Epoch

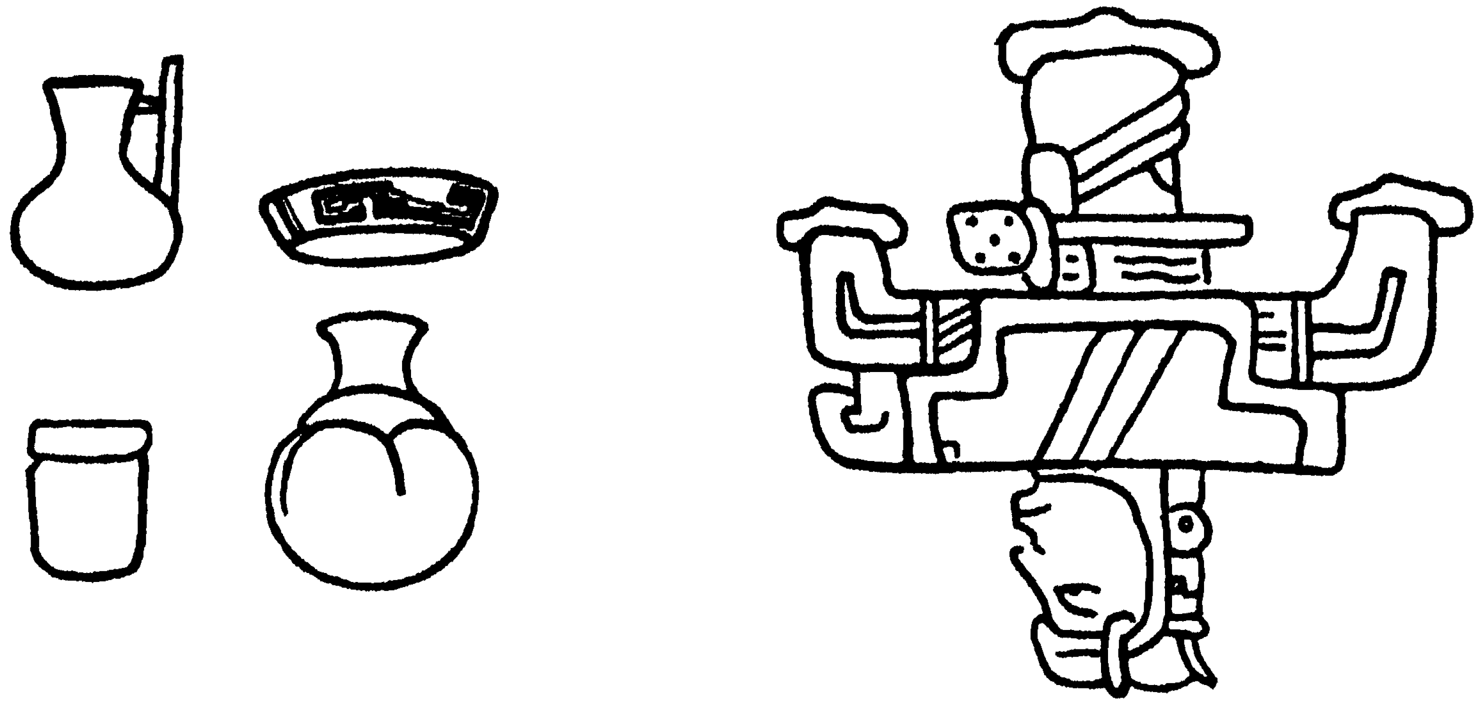
That further clues may lie in Central America is indicated by the second group of pottery at Monte Alban. This includes painted ware and several forms of vessels which are closely related to those found underlying Maya remains at Holmul and Uaxactun in Guatemala.[4] Here belong vessels with spouts and three or four legs, as well as other forms of the "Q" Complex,[5] which appear under conditions of positive antiquity in Salvador, Honduras and Costa Rica. Does the presence of these early forms imply that Monte Alban was well established before any of the Maya cities were erected? As such, it would be the oldest known city of the new world. Would such priority indicate that the Zapotecs invented the Middle American calendar, the greatest intellectual product of the American Indian? These absorbing points remain to be investigated.

Referring again to the Dancers carvings, if we were to credit them with the same age as the pottery of the first epoch, then they would appear older than anything Mayan, for even the pottery of the second epoch has the "Q" characteristics

[3] (a) George C. Vaillant, *Natural History*, xxxi: 3, 1931; (b) *Natural History*, xxxii: 6, Nov.–Dec., 1932; (c) M. H. Saville, "Votive Axes from Ancient Mexico" *Indian Notes*, Museum of the American Indian, Heye Foundation, Vol. 6, pp. 266–299 and 335–342, New York, 1929.

[4] George C. Vaillant, *Proceedings of the 23rd International Congress of Americanists in New York*, 1928, pp. 74–81.

[5] George C. Vaillant, *Anthropological Papers of the American Museum of Natural History*, Vol. xxxv, part 3, 1935.



POTTERY VESSELS OF THE SECOND EPOCH AND A CARVING
THAT MAY BE CONTEMPORANEOUS. THE SCULPTURE MAY REPRESENT THE NAME OF A ZAPOTECAN TOWN.

which seem to antedate the Maya remains in Salvador and at Holmul, Uaxactun and Finca Arevalo, Guatemala. And, of course, Type 2 did not come along until after Type 1 had gone through many stages. This takes on added significance through the discovery in 1936 of three Dancers carvings bearing typical Zapotecan glyphs like those illustrated in Caso's "Las Estelas Zapotecas."[6] Are these the oldest carved dates in Middle America?

In a recent letter, Dr. Caso says, "The finding of glyphs associated with the representations of the Dancers does not demonstrate in my opinion that these are recent, but rather that the dates are very old, which would explain their appearance in perfect form since the oldest Maya time of which we have knowledge, which is inexplicable if the Mayas did not take them from some other source."

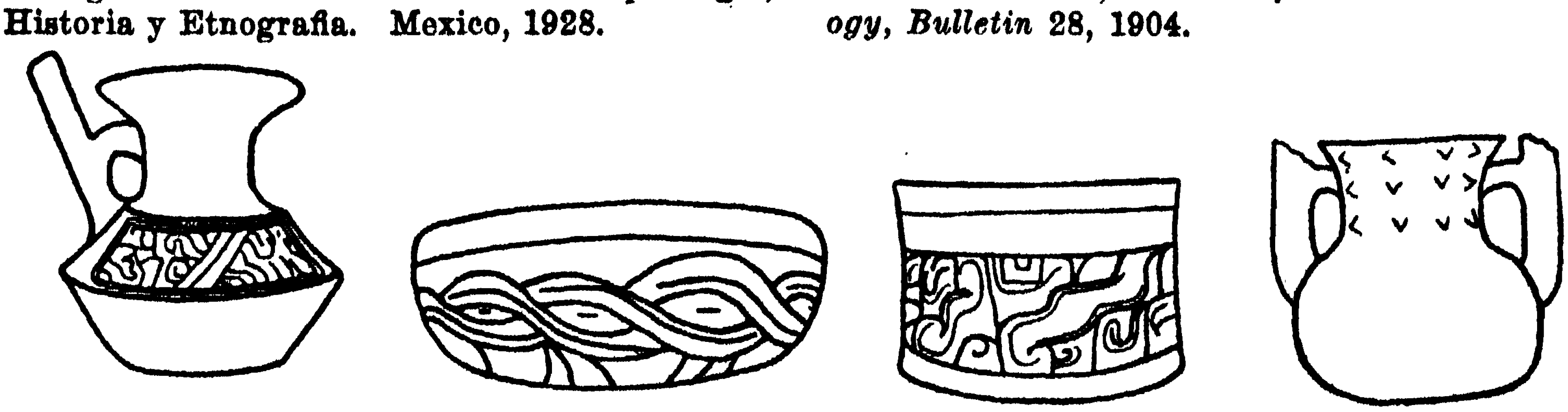
[6] Alfonso Caso, "Las Estelas Zapotecas," Monografia del Museo Nacional de Arqueologia, Historia y Etnografia. Mexico, 1928.

The German archeologist Eduard Seler had reason to propose[7] that the Middle American calendar might have originated with the Zapotecs or their neighbors, and the recent work at Monte Alban is an example of the way in which stratigraphical research can be used to inquire into avenues of thought opened by languages, history and other studies.

Third Epoch

Turning now to the next group of pottery at Monte Alban, we find indications that are truly constructive so far as history is concerned. For the pottery of Type 3 contains quite a number of forms that were used by the Maya and the Toltecs of Teotihuacan. These are vessels with low circular supports, vases with wide flaring tops and pitchers with two spouts—all characteristic of Teotihuacan. The decoration of much of this ware is engraved rather than incised,

[7] Eduard Seler, *Bureau of American Ethnology, Bulletin* 28, 1904.



POTTERY OF THE THIRD EPOCH
SHOWS CONTACT WITH THE TOLTECS TO THE NORTH AND THE MAYA TO THE SOUTH.

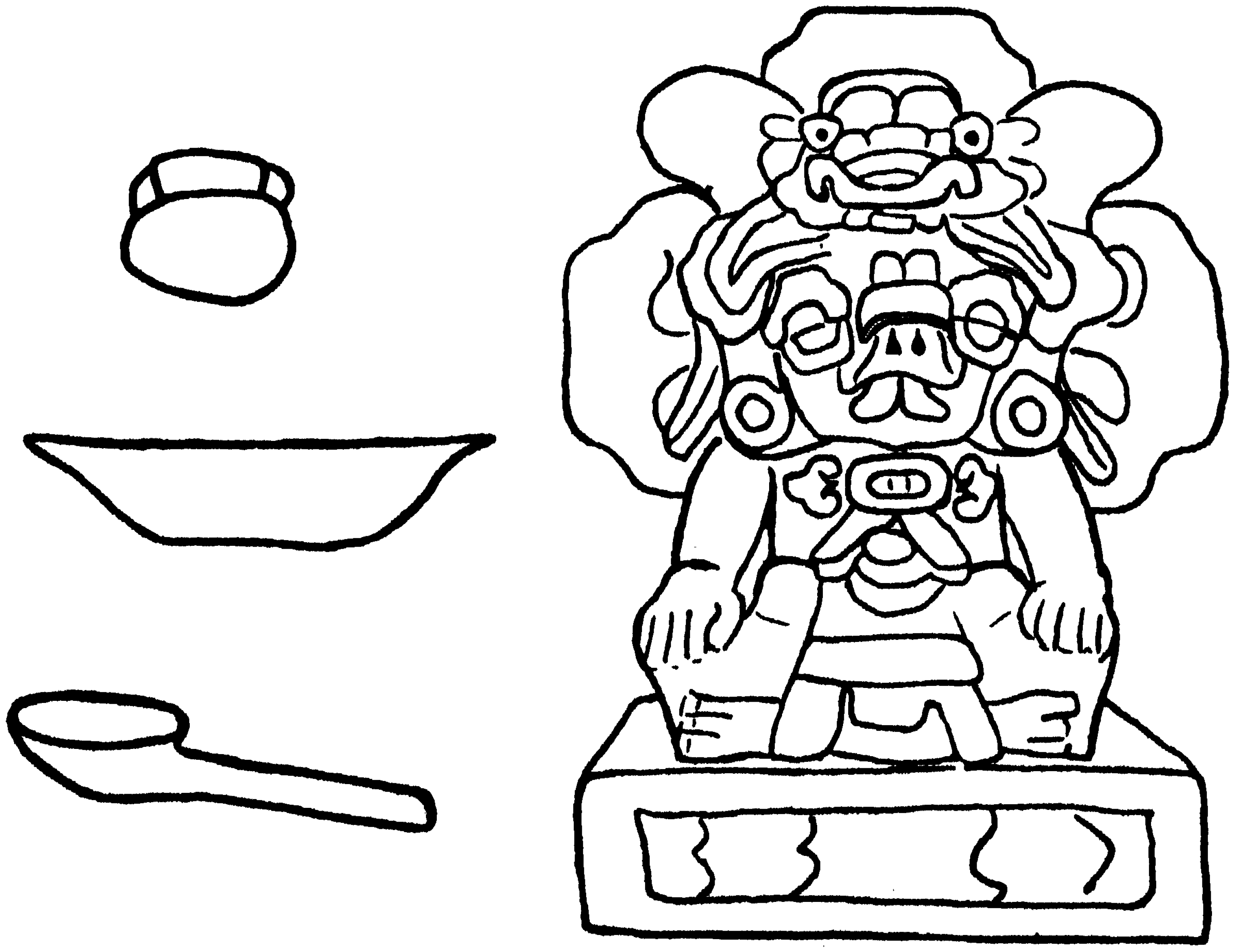
meaning that it was dug into the vessels after they had been fired. In this and in certain shapes new to Monte Alban there is reflected the influence of the Maya.

Because of these considerations it seems safe to say that during the third epoch there was extensive intercourse among the Zapotecs, the Maya and the Toltecs. Was this the time during which the knowledge of the calendar became widespread in Middle America? Was there an exchange of ideas concerning religion and architecture? To what extent were trade relations carried on, and what was their nature? These and many other challenging problems arise as soon as it is pointed out that these three important Mexican peoples were contemporaneous.

In connection with pre-Hispanic trade there looms one of the most fascinating areas awaiting investigation in all the world. This is the Chiapas-Tabasco-Vera Cruz section of Mexico. As one of the largest drainage areas of the continent, its far-reaching streams must have played an important rôle in the well-developed water commerce that linked Mexico with the United States, the West Indies, Central and South America. We have a few brief references[8] to finely carved monuments, jades and articles of metal, of commerce in salt, feathers, cacao and obsidian. We know that this region produced its own form of architecture, as at Comalcalco, where baked brick, the rarest kind of building material in ancient America, was used.[9] Yet these lowlands never have been worked systematically. Until they are, who knows what they may conceal of the history of cultural origins, the evolution of the arts and learning, the development of commerce? Was it here that the Maya people had their start? Is it true that this was one of the most densely populated regions of the world? What evidence survives here of the dramatic trek of the Toltecs, who abandoned their capital near Mexico City and migrated, some think, to Yucatan?

[8] Desire Charnay, *North American Review*, 1880–82.

[9] Frans Blom, "Tribes and Temples," New Orleans, 1926.



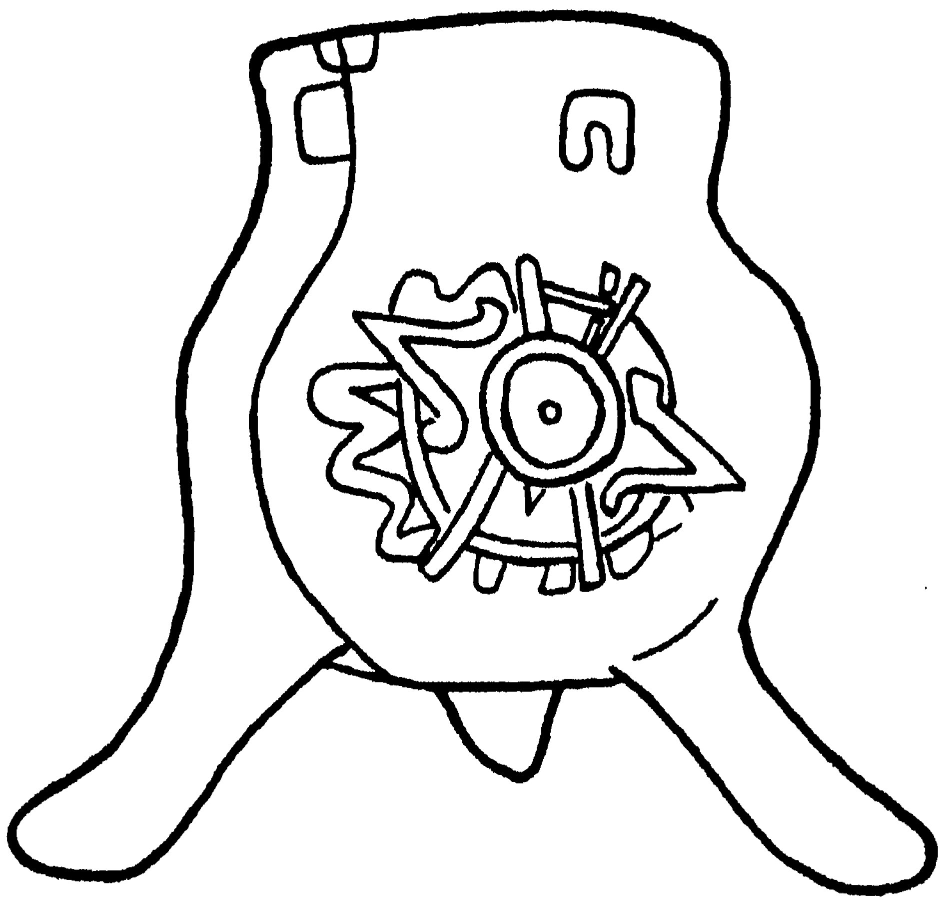
FOURTH EPOCH EFFIGY URNS

(RIGHT) BECAME VERY ELABORATE, WHILE OTHER TYPES OF WARE GREW EXTREMELY CRUDE.

Fourth Epoch

Did the Zapotecs have any contact with this gulf coast region? At first they seem to have been very much involved, to judge from the foreign ideas which they put into expression in their pottery, jades and articles of shell. How much they gave in return is not known, but at least it seems probable that they impressed the Maya with the elaborate effigy urns which they were making at the time, as reflected in the anthropomorphic incense burners and urns of Yucatan. It should be noted here that while the urns of Monte Alban became increasingly flamboyant, other kinds of ware became extremely crude.

In all Mexico and Central America, civilization centered around religion and agriculture; the loss or failure of either of these inevitably brought decay and destruction. The overthrow of the old gods and their replacement by Christianity made the fierce Aztecs completely submissive to the handful of Spaniards who conquered them, and it is believed that the Maya's wasteful methods of agriculture brought on a food shortage which reduced their remarkable civilization to ruin. Something similar seems to have happened to the Zapotecs of Monte Alban, for apparently they abandoned their sacred city during the fourth epoch. Perhaps they went to Mitla, but if so, they met with more ill fortune, as shortly before the Spanish conquest Mitla was one of the Zapotecan cities which paid tribute to a warlike people called the Mixtecs.



ONE OF THE VESSELS OF THE FIFTH EPOCH

THESE SOMETIMES CONTAIN ARTICLES OF COPPER. ALTHOUGH MONTE ALBAN IS FAMOUS FOR ITS GOLD AND SILVER, NO METAL HAS SO FAR BEEN FOUND IN ANY OF THE TYPICAL ZAPOTECAN BURIALS.

Fifth Epoch

The interpretation of Monte Alban's history does not end, however, with the cessation of Zapotec pottery at the end of the fourth epoch, for there is a fifth division which is strikingly good and noticeably different from the others. The pottery of this time is exceedingly well formed, of a good clay skilfully fired, and has a good polish. The decoration is polychrome, with brilliant colors for the calendar signs and other symbols which make up the attractive designs. The tripod support with legs in the form of animal heads is common. Its whole makeup is so different from the Zapotec tradition that it can not even be considered as a new Zapotec style.

In all Mexico there is only one group of pottery into which this ware seems to fit. That is material collected in western Oaxaca, Guerrero and a portion of Puebla. The ancient name of this region is Mixtecapan—the homeland of the Mixtecs. This land has yielded other things besides pottery, for example, the Sologuren Collection in the National Museum of Mexico, which contains manuscripts and sculptures in stone and wood displaying the calendar signs of the Mixtecs.

It is recorded[10] that shortly before the time of Spanish domination an army of Mixtecs routed several Zapotec villages and set up towns of their own on all sides of Monte Alban. Being in control of the valley, it would not have been necessary for them to use the hill-city as a fortress,

[10] Jose Antonio Gay, 'Historia de Oaxaca,'' Mexico, 1933.

as it is possible the Zapotecs had done, but there is no reason why they should not have established lookouts and used existing tombs for burying their own worthy dead. Furthermore, all the things of the fifth epoch are at or near the surface and are limited to one or two small zones, indicating a short period of occupancy and a small population.

In 1932, the discovery of 500 objects of expert workmanship attracted much attention to Monte Alban. Dr. Caso has shown[11] that among these treasures are several bearing the year sign of the Mixtecs as it is shown in the Codex Doremberg and other manuscripts from the Mixtec country. Many of the things from Tomb Seven are made of gold and silver, metals which so far have not been found in any of the strictly Zapotecan burials at Monte Alban.

In the light of these circumstances, it seems safe to postulate that the relics of the fifth epoch at Monte Alban be called Mixtecan, after the Mixtec people in whose territory the same culture traits are found.

Few portions of Middle America are more full of prospect than this Mixtec country which, because of its rugged terrain and lack of rail and motor facilities, is very little known. Virtually undisturbed, it promises in the quality of its few known yields to produce works of art that will take the place of those destroyed by the Conquistadores, and to give to the world a new conception of the genius of indigenous American art. In addition, the digging of the modern archeologist will reveal the practical side of Mixtec civilization, for even without excavating it is apparent that these people were able astronomers, imaginative builders and expert city planners.

Were the Mixtecs the disciples of the learned Toltecs, preserving up to the time of the Conquest a noble civilization which disappeared from the rest of Mexico? Will their remains establish the vague connections that seem to have existed among the Maya, the Zapotecs and peoples fathered to the north? Is there a chance that by learning more about the Mixtecs we shall be able to throw some light on the relationship of their calendar to that of the Zapotecs and the Aztecs? And may we not be able to hitch these to the Maya time count, thus establishing eventually a chronology for Middle America as full and definite as we have for Old World cultures?

These are some of the thoughts that challenge us as we read between the lines at Monte Alban, the lines being the successive layers of lowly pottery bits which can be used to tie together the thousand and one loose ends of man's past in the Americas.

[11] Alfonso Caso, *Natural History*, xxxii: 5, Sept.–Oct., 1932.

THE INHABITANTS OF NIGHT

By Professor STANTON C. CRAWFORD
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THE call of a wild animal through the darkness of night is rarely an unnoticed event. There is something about it that pulls attention away from familiar human affairs. The hearer becomes, like the animal, a creature of the senses. Thought processes give way to mere impressions. What of life-time experience or education or sophistication! Let a howler monkey send his reverberating call through the Guiana rain forest or a lynx cry from a wooded Canadian hillside at night when there is no moon, and the human auditor is one with the other forest folk, living with eyes, ears, nose—waiting for more information through the organs of sense.

Civilization demands light. Most of man's affairs are carried on in sunlight or under artificial illumination. The activities that receive his attention after nightfall are extensions of the program carried out before sunset. Man drives back the darkness, when he can, by bulb or arc or searchlight. For a whole host of other creatures the darkness of night is the normal condition of life, the accustomed field of activity. This situation must always challenge human interest and wonder. It is not one to which man is comfortably adapted. The citizens of darkness seem to belong to another realm.

Even at home, when darkness covers the familiar scenes of daylight hours, it is easy to imagine one's self in some weird, enchanted land with uncanny creatures all about. Many strange sounds come to the ears. They are magnified a dozen times by the high tension of the listener. In field or forest there is always the unseen, the partly heard. There is the soft winging of a bat, or an unheralded and soon-ended scamper through the leaves or a faint chirp or a splash in a stream. Unusual dependence must be placed on the sense of smell. There are unfamiliar and half-informative odors. Man knew this dark world once, but now it is only a tempting mystery, a realm to be explored.

In studying nature's night life, observations may be made by both silent and active hunting methods. Sometimes the observer is quiet in one place, using artificial light only at intervals to identify something that has been heard. At other times a search of bushes, tree-trunks and ground is made at close range with the flashlight for the detection of small forms. Again, there is a systematic sweeping of the higher foliage or of the forest floor at long range with the flashlight held above the head, to get reflections from watching eyes. There is a thrill in getting an answering beam from the eye of a wild thing, be it lowly hare, opossum, owl or the ocelot or a kinkajou. The color of the beam is often diagnostic—opalescent green for bullfrog, glowing yellow for raccoon, brilliant ruby red for alligator. Profitable visits may be made to stream banks and open sandy places, to straight-sided trapping pits dug along the trails and to fallen logs in the deep woods. Wharfs or points of land extending into rivers or lakes afford good listening posts for determining the activity of animals with loud calls. These sounds echo along the water for great distances.

If one is interested, he will make such hunts in many lands when the occasion offers. He will see the animals of the

world that inhabit the night. Using flashlights worked by triggers and cords attached to bait, he may cause to photograph themselves animals that he would never see. The new flash lamps easily discharged by small batteries greatly simplify this process. For watchful eyes and listening ears there is the reward of new experience. The citizens of night are seen at work and play, and representatives of almost every group of animals are included in their number. Among the smaller things there are those burrowing by day in soil or wood or in other places of darkness, and emerging after dusk. Among the larger and "higher" land forms there are those living in burrows, in caves or deep in the shade of dense copses in the daytime, and doing most of their prowling at night. That these animals should seem to prefer such life is strange to man, because he is a creature of freedom, going out openly when he pleases. Among the more likely advantages gained by the nocturnal habit are avoidance of enemies; easier acquirement of the preferred food; more effective communication by means of organs of scent and sound; and, in some cases, avoidance of excessive evaporation.

Among these dwellers in the darkness are most of the mammals. In general, these animals have large and keen eyes and ears, and an acute sense of smell. In addition, many of them possess whiskers or scattered sensory hairs, and other special tactile organs such as the muzzle of the deer. Yet some of them simply derive safety from concealment, not being especially adapted for life in the dark.

Bats are active in flight from soon after sunset on throughout the night. They fly rapidly, yet are able to avoid obstacles like branches and wires. Their eyes demonstrate an extreme sensitivity to light, but in flight heavy dependence is probably placed on the vast number of delicate organs of the tactile sense that are scattered over the wing membranes and the tip of the nose. Doubtless bats gain from their nocturnal habits a certain immunity from attack by hawks and other birds of prey.

Opossums are familiar denizens of American woods at night. In fact, most marsupials are nocturnal. The primitive Australian duckbill, too, is a night-loving form, feeding on ants by night, sleeping in a grass-lined burrow by day.

Moles and shrews are active nocturnal insectivores. The hedgehog rests safely during the day and hunts after nightfall.

The wild screaming cry of a cat is thrillingly impressive when the shades of night have fallen over a forest. Be it jaguar or ocelot, puma or tiger, lynx or catamount, it usually lies hidden by day, but wanders afar at night and preys upon many luckless smaller things. Typically nocturnal are the shambling omnivorous raccoons, which announce their wanderings with wailing cries. The badger ranges far and wide at night. The kinkajou is found in low branches in the jungle. During the night and at dusk and dawn the fox makes many raids. The coyote raises his high-pitched wailing howls to the moon at night and to the sun at dusk and dawn. The bear is a blundering nocturnal prowler. Minks, skunks and weasels are notorious marauders. The otter is abroad at night as well as by day—shy, resourceful, busy. Martens and fishers are very definitely nocturnal, and are active hunters.

The various rats and mice and many other rodents are busy while the sun is gone. The tiny deer-mouse makes the most of the protection offered by the dark ground. A muskrat jumps from a log into the stream. The giant capybara guinea-pig feeds on swamp plants along the tropical river shore. A swift agouti stops to feed on nuts and fruits. The tree holds a porcupine—snuffing, spiny,

awkward and odorous. In the darkness the beaver chisels loose his meal of bark. The rabbit nibbles green things amid the protecting shadows. The hare too is furtive, a night wanderer. Large-eyed flying squirrels are dashing little rodents of the night that spend the day asleep in hidden nests. After dusk they sail through the air from tree to tree, or land with a thud on cabin roof or on the ground.

The nights of warm countries shield startling armadillos—scuttling solitary scavengers. Silky anteaters prefer an arboreal haunt in the darkness. Sloths hang in the Cecropia trees, feeding on leaves. Resting by day, their shaggy coats colored green by an alga living on the hair, they look much like mossy plants among the branches.

Madagascar's extremely little mammal with the big eyes, *Tarsius*, is active in the trees after dark. The arboreal lemurs generally are nocturnal in habit. Monkeys and apes may be wakeful but tend to be sleepy.

The deer and its relatives feed at night, but for the most part solitarily. Their eyes glow blue and translucent when found with the searchlight. African antelopes feed much after dark, lying hidden in grasses and reeds by day. Moose and elk feed and visit the water at night. Peccaries root up their food and range in the darkened forests, especially at dusk and dawn.

The heavy tapir lies in dense cover by day, and comes out when it is dark to feed and bathe in the river. The elephant visits water to drink at night. The rhinoceros too feeds and meets with his kind at the water holes.

Birds that are nocturnal in habit frequently have large eyes, with pupils capable of exceptional dilation to admit a maximum number of rays of dim light. Typical night-loving ones are the velvety-winged owls and goatsuckers. Adaptations exhibited by these birds are the ability to fly noiselessly and to see well in darkness. The goatsuckers have wide mouths with hairy margins, used to trap insects while they fly swiftly through the air. Their loud call, be it the "whip-poor-will" of the States or the "who-are-you" of Guiana, is appropriate for the communication of animals living solitarily in the dark. What better medium than voice and hearing for long distance communication when the world is quiet and enemies sleep! In the darkness their eyes return a dull glow when flashed with the electric torch.

The night heron is both crepuscular and nocturnal. The killdeer may feed after dark. Wild ducks fly, call and feed in the moonlight. The mocking-bird releases a flood of music amid silvery shadows. Other birds occasionally call, among them the tinamous, fowls, nightengales, catbirds, robins, song sparrows, chipping, white-throated and vesper-sparrows, Carolina wrens, rose-breasted grosbeaks, yellow-breasted chats, upland plovers, snipes, woodcocks, wood peewees and pheasants.

Much bird migration takes place at night. Among the nocturnal migrants are golden plovers, sandpipers, curlews and lapwings, the larks and thrushes. The birds fly surely, whether over land or sea, unless diverted by bright lights such as those of lighthouses. Too often they dash themselves to death against the glass housing of these bewildering searchlights.

Among the reptiles there are numerous representatives of nocturnal habit. Crocodiles, caymen and alligators are active throughout the night, swimming and bellowing whether the moon is up or not. These reptiles produce musk from skin glands beneath the chin, especially during the breeding season. The powerful odor, which doubtless serves as a means of recognition, is said to be produced by animals of both sexes and mainly at night.

Anacondas are especially alert at dawn and dusk, hunting beside streams. In the snakes, the tongue is a very sensitive structure supplementing the other sense organs. Such poisonous reptiles as the Central American bushmaster and the rattlesnake are abroad in the darkness. In these vipers the pit between the eyes and the nose is richly supplied with nerve endings, and is believed to be useful in detecting air vibrations. Some gecko lizard and turtle species are active at night.

Among the amphibians the night time is preferred for activity because it furnishes best protection for damp skins. Frogs engage in gentle croaking, and toads hop abroad in search of insects. Tree-frogs are heard from sunset to sunrise, being most vocal for a few hours following dusk. Salamanders are retiring creatures, feeding and laying their eggs in the darkness.

Fish are active at night. They come to bait on lines and in traps, and are often heard leaping in quiet water. The flashlight will reveal swarms of small fry in shallow water where they would not venture in daylight.

These and many others are the night's true citizens, very much at home whether in the moonlight or in the complete blackness of foggy and cloudy nights. They inhabit the hills and the valleys, treetops and the deep grass, rocky hillsides and the banks of quiet streams, reedy swamps and the waters of shimmering lagoons. We may wander far in the darkness and hear some, but see few of the nocturnal animals, although many furtive eyes and sensitive ears and noses have doubtless appraised us. We humans can only strive to interpret the scents and sounds that will inform us about new acquaintances, and seek to renew our elusive knowledge of the old ones. In these eastern hills at any rate, when the shadows are dark among the blue beeches and alders and the sunset glow is fading from the upland pastures, when the frogs join chorus and the call of the screech-owl comes from the darkened trees, it is difficult to turn away and go indoors.

THE ABILITY TO JUDGE SEX FROM HANDWRITING

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SINCE Binet's[1] early experiment on the judgment of sex from handwriting, several investigators have attempted to discover how much truth there is in the contention of graphologists that sex in handwriting can be distinguished to a significant degree. Binet collected 180 addressed envelopes, the majority of which had passed through the mails. Ninety-one of these were addressed by men and eighty-nine by women. These specimens of handwriting were submitted to fifteen untrained judges and to two handwriting "experts," and judgments were made as to the sex of the writers. Binet found that the "amateurs" judged sex correctly in 65.9 per cent. to 73 per cent. (average 69 per cent.) of their judgments, while an "expert" graphologist was successful in from 75.7 per cent. to 78.3 per cent. of his judgments. He also found that under very favorable conditions an "expert" may judge the sex of a writer correctly in about 90 per cent. of his judgments.

Downey[2] repeated Binet's experiment, introducing a few variations. She collected two hundred envelopes, all addressed to a woman; half were written by men and half by women. The writers were representative of a great many different professions. She used thirteen judges, all untrained, varying in age from fifteen to fifty. The number of correct judgments ranged from 60 per cent. to 77.5 per cent.

Newhall[3] conducted a similar experiment, collecting two hundred mail addresses, half of which were written by each sex without the writer's knowledge of their future use. While most of the judges were in their twenties, the ages of the writers varied from twenty to sixty. The mean of correct judgments was 57 per cent., with scores ranging from 56 per cent. to 59 per cent.

Kinder[4] had one hundred subjects, equally divided as to sex, write the sentence, "The dog jumps quickly over the fence after the lazy brown fox." This sentence was submitted to twenty women college students. The range of correct judgments was from 58 per cent. to 76 per cent., with a mean of 68.4 per cent.

Broom, Thompson and Bouton[5] collected at random forty handwriting samples of the sentence, "Now is the time for all good men to come to the aid of the party." Eighteen men and twenty-two women submitted these specimens, and twenty-two "amateurs" and two penmanship teachers did the judging. A second set of judgments by the same judges was secured after an interval of two weeks, thus making possible a check on reliability. On the second series the mean for the men was 68.3 per cent. and for the women 71 per cent. correct.

Young[6] collected specimens of hand-

[1] A. Binet, "Les Révélations de l'Ecriture d'Après un Contrôle Scientifique," Paris, Alcan, 1906.

[2] J. E. Downey, *Psychol. Rev.*, 17: 205–216, 1910.

[3] S. M. Newhall, *Jour. Applied Psychol.*, 10: 151–161, 1926.

[4] J. S. Kinder, *Jour. Educ. Psychol.*, 17: 341–344, 1926.

[5] M. E. Broom, B. Thompson and M. T. Bouton, *Jour. Applied Psychol.*, 13: 159–166, 1929.

[6] P. T. Young, *Jour. Applied Psychol.*, 15: 486–498, 1931.

writing from college juniors and seniors, all specimens coming from regular class work. The judges, twenty-five men and twenty-five women, were all untrained. The range of correct judgments for this group was 48 per cent. to 72 per cent., with a mean performance of 61 per cent.; the men and women had about equal ability to make correct judgments.

The author, in an unpublished study, selected at random twenty-four college students (twelve men and twelve women), who were asked to write on small cards the sentence, "A good name is rather to be chosen than great riches." These subjects were told that the handwriting samples were to be used for experimental purposes, and, although they were instructed to write as they usually do, it could hardly be supposed that some of them did not take more than ordinary care with their handwriting. However, knowledge of the fact that an experiment was in progress apparently did not affect the results materially, since the results of this investigation compare very favorably with other studies in which such knowledge was not known.

All subjects used the same fountain pen. The cards were numbered on the back; those samples by men were given even numbers and those by women were given odd numbers. The twenty-four cards were then submitted to two hundred college student judges (one hundred men and one hundred women), all of whom were inexperienced. At all times the attempt was made to keep the "experience factor" as nearly constant as possible. All those who provided handwriting samples were college students and were, therefore, doing approximately the same amount of writing. At least, they were keeping in practice.

The two hundred judges were asked to separate the cards into two piles, the first containing those specimens judged to be men's writing, and the second containing those specimens judged to be women's writing. The judges were permitted to go back over the specimens and to take as much time as they wished.[7] It was noted that the women judges took more advantage of this opportunity than did the men, and this may account for the better scores made by the former. During the entire study a careful observation was made of some of the chief characteristics that the judges were looking for in judging the handwriting specimens. The following were the most frequently mentioned reasons given by judges for choosing of sex from the handwriting samples:

(1) A woman's writing is neater.
(2) Women write more slowly and achieve greater finish.
(3) A woman's writing is prettier.
(4) Men tend to dot the "i" with a dash instead of a small dot.
(5) When a man does write well, his writing is likely to be almost perfect.
(6) Men write larger than women.
(7) Any backward writing or printing is likely to be the writing of a woman.
(8) When an "e" is made ε, it is likely to indicate a woman's writing.
(9) A woman's writing is likely to be more readable than a man's.
(10) Men press harder on their pens than women.

After each judge had finished separating all the cards into the two piles, the score was tabulated in terms of successes and errors of judgment. The recorded judgments made by men and those made by women were kept separate in order that any possible sex differences in ability to judge might readily be determined. An analysis of the records indicated that the men judged sex correctly in 59.3 per cent. of their judgments, while the women averaged 64.3 per cent. (a mean of 61.8 per cent. for both sexes). The individual

[7] Downey did not allow her subjects to go back over the set of handwriting specimens a second time; she apparently was of the opinion that first impressions are most valuable in a study of this kind. Indeed, something may be said for such a procedure.

mean score for men was 14.25; for women, 15.44; for men and women, 14.84. There was evidence of wide variability in individual accomplishments. For example, one judge had a score of only six judgments correct out of the twenty-four trials; three judges received a score of nine, twenty-two a score of twelve (chance expectation), twenty-four a score of thirteen, thirty-seven a score of fifteen, thirty-four a score of sixteen, and two a score of twenty.

All the experiments referred to above indicate that the sex of a writer can be determined in a manner superior to chance. Also, women judges appear to be able to judge sex from handwriting slightly better than men. The majority of experimenters are of the opinion that certain types of writing may be classified roughly either as a "masculine hand" or as a "feminine hand" on the basis of a few characteristics which have been designated as masculine or feminine, "sex signs." Thus Newhall, in speaking of some of his specimens, says: "In these 20 extreme cases one is struck by the angles, irregularity, and verticality of the feminine."[8] Of course, there is by no means a *marked* difference between masculine and feminine handwriting; inversions of sex signs are frequent, such as men writing a "feminine hand" and women writing a "masculine hand." Downey believes that training has much to do with what is termed "sex differences in handwriting." For example, women who write a man's hand are likely to be those who lead a literary or professional life or who, because of experience or age, have had extensive practice. On the other hand, men who write a feminine hand are likely to be teachers (a profession which encourages conventionality) or else are those accustomed to much writing.

[8] *Op. cit.*, p. 161.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

MacDONALD SAW SCIENCE AS AID TO BETTER HUMAN LIVING

The last public utterance of the late Right Honorable J. Ramsay MacDonald was a discussion at the Royal Institution, London, on how science affects the community. The ex-Prime Minister viewed science from the standpoint of years of heavy government responsibility, tempered strongly by the previous years of labor leadership.

"In all public affairs," he said, "I myself am an unrepentant evolutionist. There must be changes, not for the sake of change but because social harmony and progress require it."

He felt that use of the scientific method might prevent the pain and unrest in individual and community that uncontrolled change and disruption entail.

As an antidote to the feeling that machines, typifying science, snatch jobs away from laboring humanity, Mr. MacDonald suggested that science can provide the antidote. It consists of leisure and culture, which will enable us to rediscover the qualities of life which modern society is said to have lost.

Scientific invention properly used, Mr. MacDonald believed, will reduce cost of production without lowering standards of life, as some have feared.

The blame leveled at scientists for the horrors of war was denied by Mr. MacDonald, who held that peace or war is not the responsibility of scientists as scientists, so long as their discoveries, which increase our peaceful and beneficial resources, can be used for war machinery. Scientists as such can not stop war.

Recent experience convinced Mr. MacDonald of "the urgent desirability for close cooperation between the scientist, the industrialist, and the man of affairs, to enrich the lives of human beings, to help such changes as will diminish the disruptive forces in society, and to promote social solidarity which lies at the root of human progress and happiness."

MINE STUDIES AND THE ORIGIN OF COSMIC RAYS

In their studies of piercing cosmic rays scientists have scaled lofty mountains, risked death in balloons, sailed the oceans and probed the depths of deep lakes. Cosmic ray research, indeed, rivals the epics of geological explorers in romantic adventure. But one ought not let the romance obscure the significance of these researches. The case of deep mine studies of cosmic rays, just reported by Dr. Volney Wilson, of the University of Chicago, is typical.

Dr. Wilson probably looked romantic as he donned a crash helmet and made his measurements 1,600 feet within the earth, in the ghostly dimness of a Michigan mine. The importance of his work, however, has little to do with miners and the hazards of mining. Through that 1,600 feet of rock came weakly cosmic rays, the most penetrating radiation man has ever studied. What caused this radiation? In a letter to the writer, Dr. Wilson gives hint. "The cosmic rays observed in deep mines are much more penetrating than is to be expected for either photons or electrons, which constitute the most penetrating radiations known before the discovery of cosmic rays," he states.

"Within the last year particles called

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

'heavy electrons' have been identified in cosmic rays. These are much more penetrating than electrons, which are believed to comprise most of the cosmic rays found at high altitudes.

"It is questionable, however, whether these heavy electrons are penetrating enough to account for the rays observed in deep mines. Perhaps we have here effects produced by the neutrinos, particles predicted by the Italian physicist Fermi and used by Nobelist Werner Heisenberg to account for penetrating cosmic rays. There is reason to believe from the deep mine experiments that there are two kinds of penetrating cosmic rays. It is not impossible that one of these consists of heavy electrons and the other of neutrinos."

THERMAL NOISE USED IN STUDIES OF HEARING

Some of the newer experiments on fundamental problems of human hearing are using one of the strangest sounds in the world—the sound without a pitch, or said another way, the sound that is all sound.

No, this is no riddle! There really is an unpitched sound which contains all the sound wave frequencies from about 20 vibrations at the lower limit of hearing to 15,000 vibrations a second, which is near the upper limit of human audibility.

Few people have ever heard this sound, which can create a continuous acoustical spectrum of frequency. Scientists call it thermal noise. Its origin is in the haphazard motions of the tiny electrical charges known as electrons, as they move in chaotic, bumping paths within an electrical conductor. Cause of this electron motion is the temperature of the wire.

You will have no chance of hearing thermal noise merely by holding a wire close to your ear and listening. The thermal noise is electrical rather than acoustical noise. To hear it you must amplify it millions of times and make the electrical energy operate a loud speaker. If you amplify sufficiently there will finally come a dull roaring which becomes stronger and stronger with increased amplification. This is thermal noise.

In electrical and radio engineering thermal noise represents the limit of useful amplification just as the appearance of grain in a photographic picture represents the useful limit of photographic magnification. If you have a powerful radio, part of the background noise is thermal noise. It is somewhat similar to the surface noise of phonograph records.

TWELVE KINDS OF SNOW RECOGNIZED BY SCIENCE

To most of us to whom snow only means a job of shovelling, it may help a bit (at the next siege of back-breaking exercise) to learn that scientists classify snow into at least 12 different varieties. Right off, there is falling snow and fallen snow. That's easy. And some of us have recently learned about powder snow through the present trend to skiing.

But did you ever hear of sand snow or wild snow or sun-crust or rain-crust snow?

Let's start with falling snow. It is precipitation frozen into some type of crystalline form. When it hits the ground it becomes fallen snow. At first fallen snow is powder snow, soft, fluffy and feathery and not unchanged from its in-the-air condition. Skiers look for it.

But powder snow, if it comes to earth at very low temperatures, may form sand snow, on which neither a ski nor sled will glide. Greenland explorers have reported sand snow. Wild snow is another form of powder snow, which falls in a complete calm at low temperature and is immensely unstable.

Following first contact snow enters the stage of settling snow. It becomes settled snow, which can take the close-lying

powdery form which makes the best of all skiing.

The next stage in snow's evolution is to pass from the new to the old snow classification and the state of new firn snow is reached, where the snow is becoming granular and compacted. Variations of firn snow include the sun-crust and rain-crust forms where melting occurs, and then freezing, with a crust resulting.

Finally advanced firn snow arrives, which turns either into firn ice or glacier ice.

BY-PRODUCTS OF GASOLINE

Coal, particularly its sticky, uninviting tar, has been the wonder raw material of chemistry, showering the world with a multitude of dyes, drugs and other products.

Petroleum, considered useful primarily as a source of oil and gasoline for motor fuel, is being demonstrated as the source of hidden chemical riches.

This modern metamorphosis of oil is accomplished by the process of cracking, which consists of distilling the petroleum under heat and pressure to separate out its various components.

Cracking produces many more gallons of better gasoline than nature can manufacture. Dr. Gustav Egloff, research chemist for the Universal Oil Products Company, calls the cracking process a mighty conservation measure because without it some two barrels of crude oil would be needed where only one is used to-day.

In addition to motor fuel production, cracking has allowed the chemist to synthesize new substances from crude oil and to found new industries. It has given birth to a host of new products such as polymer and iso-octane gasolines, lubricating oils, drying oils, resins, ethers, alcohols, glycols, chlorinated compounds, alkylated paraffins, aromatics and phenols.

The unsaturated gases and liquids or their derivatives from cracked products have found important uses in ripening of fruits, as growth promoters and for maturing potatoes and nuts. Ethylene and propane have found application as anesthetics in surgery.

The day is foreseen when the chemist will give industry essentially pure hydrocarbons from petroleum instead of the complex mixtures of our present gasolines and lubricating oils.

It is predicted by Dr. Egloff that the motor fuels of the future will be composed of but few if not single hydrocarbons, with more than double to-day's efficiency. Just now the fuel is ahead of the motors, as the chemist has ready an aviation motor fuel with an octane rating of over 100. It is a 50–50 mixture of iso-octane and isopentane with tetraethyllead added. No engines now available will utilize efficiently that quality of fuel.

LEAVES SHELTER ROOTS FROM RAIN

Plants hold their leaves over their roots like umbrellas, thereby preventing much rain that might otherwise reach them from falling all the way to the ground. To that extent plants are their own enemies, at least in times of scanty rain.

That trees do this sort of thing is something we have all experienced. Who has not sought shelter under the thick canopy of a big tree during a shower, even though weather-wise advisers counsel against it because of the lightning risk?

But even humbler plants, the herbs of the prairies and meadows, also hold up leaf-umbrellas against these possible benefits to their roots. Dr. O. R. Clark, of the University of Nebraska, has made elaborate measurements of rain-interception by leaves of prairie herbs, which he reports in the weekly journal, *Science*.

Dr. Clark simulated conditions of na-

ture as nearly as possible. He laid out squares of prairie vegetation of known area ("quadrats"). One fifth of each quadrat had the plants growing in shallow pans buried to the edges, so that the amount of water reaching the soil could be accurately measured. Water was supplied as artificial rain from sprinkler bottles.

The proportion of water intercepted by the leaves varied greatly with the intensity of the artificial showers. A gentle one, of one eighth inch in 30 minutes, could get only 26 per cent. of its water through a covering of buffalo grass to the soil beneath. A harder rain, a quarter inch in 30 minutes, sent 69 per cent. of its moisture through to the ground. A downpour of half an inch in half an hour got 83 per cent. of itself through.

These interceptions of rain are practically all net loss to the soil, and of course also to the thirsty roots that are in the soil. The totals per acre are enormous. For instance, Dr. Clark calculates that wheat, intercepting 52 per cent. of half an inch in half an hour, causes a loss per acre of over 29 tons of water.

MAGNESIUM COMPETES WITH ALUMINUM

Over in the densely wooded hills of Austria near the little town of Karnten is an American-controlled company that, in four years, has upset the world markets of valuable magnesium and hence is now a potential factor in the use of aluminum, magnesium's rival among light-weight metals.

Tremendous ore reserves of magnesite —whole mountains of it in fact—have enabled Austrian electrochemists to produce pure magnesium for 30 cents a pound. And at this price it is feasible to make light weight alloys that find use in airplane construction. Germany, just to the north of the plant of the Austro-American Magnesite Company, is turning out magnesium at a rate estimated as great as 12,000 tons a year, although definite, certain figures are lacking. Somewhat similar in obscurity is the situation in Japan, where it is known, however, that mountains of magnesite exist in Korea. Outside of Germany and Japan world production of magnesium is only about 7,000 tons.

Thirty cents a pound for magnesium is close to aluminum's cost of about 20 cents a pound. Magnesium's low cost comes primarily from the ease of mining. In Austria magnesite is mined on the mountain tops and flows, by gravity, to the plant. Mining cost is only 50 cents a ton, whereas it costs as much as $35 a ton to mine aluminum ore in some cases. "Burning" the magnesite to free it of its oxygen is as cheap as burning lime.

The Austro-American Magnesite Company is an important producer of magnesite roof brick for blast furnaces and also makes sound-proof brick. The latter is composed of magnesite cement embedded with wood chips, which are abundantly available in the Austrian hills around the plant. It has the most modern of equipment and one of the world's longest tunnel kilns, 350 feet in length.

COMPOUNDED WOOD

The old practice of veneering furniture, which turned out a mahogany table for $5, is back in a new and much more fundamentally important form.

Compounding wood, as the process of veneering is known to the trade, is now turning to the new field of making wooden beams which have all the uniformity of characteristics of steel and other metals. Do you wish a wood with a given density, a given elastic strength and other properties? Compounded wood is the answer, and each time you place an order with the mills it comes through the same, time after time.

Wood unsuited for many construction purposes becomes the core of the plank

and laminated layers supply the exterior. The proportions of each are varied so that the same characteristics can be repeated at will.

In part the use of phenolic resins as the gluing agent in the finished board is the difference between older veneer panels and the new beams of technologic mill working. The various layers of wood are arranged in "books," dried, coated with the resin, heated electrically and finally pressed at proper temperatures into finished lumber.

"These boards," states the Industrial Bulletin of Arthur D. Little, Inc., "meet predetermined specifications, with widths previously unavailable, and with a uniform adherence to specification comparable to that of the steel construction industry."

The resin used in the process impregnates the board with vapors which are obnoxious to fungi, and thus the long-sought fungus-proof board is at hand.

THE GROWING USE OF TIN CANS

Tin cans, some 12,000,000,000 of them annually, take to market and American homes a vast variety of products. They constitute the product of one of America's great industries, which used in 1933, for instance, more steel than buildings, or railroads, or any other steel customer except the automobile industry.

It would be more accurate to call them steel cans, for the tin upon them is a very thin layer, and there is chance that in the future enamels, such as used now on the interior of food and beer cans, will make it possible to produce satisfactory cans without tin.

There are about a hundred cans produced in this country for each man, woman and child, and only some 60 per cent. of them are used for food. John E. Burchard, writing the can's saga in *Technology Review,* reminds us that tobacco, oil, paint, shoe polish, aspirin, moth balls, stamp pads and hundreds of other things come in tin cans.

The origin of the tin can goes back to Nicolas Appert, a Frenchman, who developed a method of preserving food in 1804. It was essentially the method used to-day: Heating the food and putting it up in containers sealed against air.

Appert used glass bottles mostly, and he can therefore be claimed by the glass container industry as a progenitor. But he also tin-plated metal containers with some success.

While glass and metal compete with one another in serving us with food and drink, the fiber container is making its bid for favor. For daily deliveries of fresh milk, a rectangular "paper bottle" is being produced and used. It has the advantage of not having to be returned. It does not have to be recleaned and sterilized. Made square for economy of space, it is automatically filled and sealed by machinery. This new container promises to find its way on many more front steps in the early morning hours of the future days.

CONQUEST OFFERS NO ESCAPE FROM POPULATION PROBLEMS

Crowded peoples press distracted rulers into national policies that offer no hope for solution of their problems. The two measures most favored in recent times, conquest and encouragement of migration, are illusory hopes, declares Dr. Isaiah Bowman, president of the Johns Hopkins Universtiy, in the introduction to a new book. "Limits of Land Settlement," published by the Council on Foreign Relations. Each of the ten chapters is contributed by an acknowledged authority in the field of human geography.

"One conclusion stands out above the rest," Dr. Bowman sums up. "New land will accommodate too slow and small a stream of population to be of real social importance to the countries of origin. In our present nationalized world, in which the best lands have been occupied, and

restrictive measures are in force, migration is no answer to economic and social strain induced by so-called overpopulation.

"Nor is military conquest either a practical or a rational answer. The struggle for additional territory as a step in empire building can be understood; the hope that it will furnish an offset to a high birth rate is based upon an illusion.

"No discernible or predictable stream of migration can keep pace with the birth rates of conspicuously overcrowded countries."

Those who still do go a-pioneering have to be helped along by their respective home governments. By one school of thought, says Dr. Bowman, this is taken to mean that the old pioneering spirit is gone and that the present generation of would-be settlers is "soft."

But this philosophy, he answers, may be said to ignore the fact that "things were never as they used to be." In our own land, the Lords Proprietor in colonial days, and the special concessions to canals and railroads later, were early manifestations of the same "colonist coddling." It is only reasonable to expect that inducements must be held out to prospective pioneers, as offsets to the hardships they know they will have to endure.

JAPANESE IN BRAZIL RAISE EASTERN CROPS

Crops of the Far East are being added, one by one, to Brazil's standbys, coffee and rice. And Japanese farmers are doing a large share of the labor, in Brazil.

For some years, recently, it has looked as though Japan might find the great spaces of Brazil very useful to absorb hordes of immigrants. More and more Japanese sailed for a promised land in this part of South America, heading particularly for southern Brazil, where colonies of their nationals were growing fast.

By 1934, Brazil found herself getting more immigrants from Japan than from any other land, except Portugal. In that one year, 27,000 Japanese arrived.

And then, the Brazilian congress sharply closed the doors of the country, to a comparatively narrow crack. Japan could send 2,000 people, no more, in a year. As the situation stands, about 150,000 Japanese are established colonists in this South American country, most of them in the state of São Paulo.

Describing an important colonial settlement of these people, Professor Preston E. James states in the *Geographical Review* that the town proper is like others of tropical Brazil. But around it is old Japan—farm buildings, rice and tea fields, even feathery bamboo.

Between 1932 and 1934, he says, Brazil's Japanese farmers "dominated the new crops that have recently started to compete seriously with coffee. They produced 46 per cent. of the cotton, 57 per cent. of the silk, and 75 per cent. of the tea."

He adds that figures for the state of São Paulo reveal facts "that must make every interpreter of lands and peoples stop and think." Japanese make up only 18 per cent. of the people there, and occupy less than two per cent. of the farm land. But they account for 29.5 per cent. of São Paulo's agricultural production.

FOREST GAME MANAGEMENT FACES PROBLEM OF SURPLUS

Game management has been for so long a matter of saving the fragments that this generation still thinks of it in terms of conservation only. But the simple command, "Don't shoot!" no longer covers the case. In many places a more liberal, though still regulated, policy of game removal seems now in order.

One of the points laid before the meeting of the Society of American Foresters in Syracuse, N. Y., last week, in an address by Dr. Homer L. Shantz, chief of the division of wildlife management of the U. S. Forest Service, was the over-

crowding of parts of the big-game ranges in the national forests.

"Deer protected by a buck law and control of predators have over-used their range, especially in winter," Dr. Shantz said. This is true in both western and eastern forests.

The fact that deer know no man-made, legal boundaries complicates the problem. In summer, the range within the national forests takes adequate care of the herds. In winter, they migrate out of the jurisdiction of the Forest Service, into lands where their needs are not taken adequately into consideration. Too often the result is winter starvation. In their more restricted habitats, elk present something of the same problem.

The solution does not necessarily consist in shooting the deer until the herds fit the present range. A possible alternative, more pleasant for most of us to contemplate, is to enlarge the range to fit the herd. Or, more exactly, to enlarge the winter range until it balances the summer range in sustaining capacity, and then seeing to it that the herd stays within this balanced capacity.

The governing principle, Dr. Shantz emphasizes, is that biological needs shall decide action rather than dogmatic fiat.

THE INCOME OF PHYSICIANS AND LAWYERS

Does a plumber really make more money than a physician? Are teachers the poorest paid of white collar workers?

Such questions as these, although extremely important to those planning their life work, have been without answers because no figures have been available on comparative life earnings in different occupations.

Daily or weekly wages do not offer such a basis of comparison, for in some lines of work, pay is small at first but increasing over a long period of years. In others, pay is high at the outset, but likely to terminate abruptly and be interrupted by periods of "slack" or idleness.

Interesting, therefore, is a series of estimates prepared by Dr. Harold F. Clark, professor of educational economics at Teachers College, Columbia University, for the journal *Occupations*.

Highest paid are the physicians and lawyers, Dr. Clark found. An average member of these professions may expect to earn during the whole course of his lifetime a total of $117,000. Dentistry, engineering and architecture hold second place with a life's earnings amounting to $108,000. Next come college teaching and social work with $74,000 and $51,000 respectively.

Midway down the list are journalism and the ministry. A journalist may hope to earn a total of $44,000 during his lifetime; a minister $46,000. Next come library work, public school teaching and the skilled trades. These are followed by nursing, unskilled labor and farming.

Last on the list of occupations is farm labor. An average farm laborer may make only $12,000 during his whole lifetime. That is what the average physician would make in between two and three years of his highly skilled service.

Dr. Clark's estimates, he points out, are not accurate. For some professions they may vary as much as 45 per cent. from the correct figure; for others they probably hit within five or ten per cent.

SAN MIGUEL ISLAND, CALIFORNIA

By Professor T. D. A. COCKERELL
DEPARTMENT OF ZOOLOGY, UNIVERSITY OF COLORADO

OFF the coast of Southern California, for the most part in plain sight from the mainland, are eight islands. They are divided into two groups, northern and southern. The northern islands, arranged in a row east and west, are San Miguel (the outermost), Santa Rosa, Santa Cruz and Anacapa. The southern are Santa Catalina, San Clemente, Santa Barbara and San Nicolas. Geologists suppose that during the Tertiary Epoch there was a land, which has been called Catalinia, extending from the northern islands southward, including the southern islands and the vicinity of San Pedro on the present mainland, and possibly going as far as Guadalupe Island, far out in the Pacific. How much of this land persisted into the Pleistocene remains uncertain, but during the latest geological peroid there were undoubtedly great changes of level. During the Tertiary, maritime conditions are shown by the presence of numerous Eocene and Miocene sea shells fossil on Santa Cruz. Chaney and Mason postulate a peninsula in Pleistocene times, extending westward from south of Ventura and including all the northern islands. This leaves us to suppose that the southern islands were independently connected with the mainland, but there is a comparatively shallow bank (the greatest depth 96 fathoms) extending from Santa Rosa to San Nicolas. That the islands were really connected with the mainland during the Pleistocene appears to be proved by the occurrence of remains of mammoths (Elephas) on Santa Cruz, Santa Rosa and San Miguel, and the endemic salamanders (Batrachoseps) on Catalina and the northern islands. Chaney and Mason describe a formation of Pleistocene age, on Santa Cruz, containing a flora similar to that in the vicinity of Fort Bragg, about 440 miles N.–N.W. This includes large logs of Douglas fir (*Pseudotsuga taxifolia*), wood and cones of cypress (*Cupressus goveniana*), seeds of *Garrya elliptica,* and in general a flora differing almost entirely from that now on Santa Cruz and not ancestral to it. The only species still existing on Santa Cruz is the pine tree, *Pinus remorata,* which must formerly have had a very wide distribution, since it is found on Cedros Island, off the coast of Lower California. We apparently must conclude that a Pleistocene fauna and flora which inhabited the islands at one time has entirely or almost entirely disappeared, to be replaced by the quite different assemblage we find today. When these changes took place, and under what conditions, we do not know. Munz gives a list of 35 kinds of plants, found to-day on the northern islands, which occur on the mainland mostly from Monterey County northward. These may well have inhabited the mainland of Santa Barbara County (one of them, *Vaccinium ovatum,* does so to-day[1]) when the climate was moister.

Whatever may have been the history of the islands, they are of great interest to the biologist to-day on account of the large number of peculiar (endemic) species and races found upon them. Taking the islands as a whole, there are about fifteen endemic mammals, fifteen birds, two lizards, two salamanders, sixteen land mollusks and over eighty flowering plants. Many insects are apparently en-

[1] As shown to me by Mr. M. Van Rensselaer, who also pointed out a grove of Lithocarpus, a tree not cited by Munz in his "Flora of Southern California."

demic, including a quite distinct butterfly on Catalina. Numerous fungi have been described from Santa Catalina, but whether any are truly endemic is uncertain. Some of them are found on introduced plants, such as Eucalyptus and *Nicotiana glauca.* These endemics may be classified under two headings. First, the relict endemics, which must have been much more widely distributed in former times, but now survive only on the islands. Second, the true island endemics, which acquired their special characters on the islands. Of the former type must be the wholly endemic genus of trees, Lyonothamnus, of which there are two forms, one only on Catalina, the other on Catalina, San Clemente, Santa Cruz and Santa Rosa. To the latter group we must assign the island foxes, having special races on Santa Catalina, San Clemente, San Nicolas, Santa Cruz, Santa Rosa and San Miguel. No one could imagine that there were six kinds of these foxes on the mainland, and on the islands being formed each took one for its own.

Although the ancient Catalinia is presumed to have included all the islands, this is of no particular significance in relation to their present population, which must in the main date from quite late Pleistocene. It has been supposed that there were two extensions from the mainland, one in the north, as already indicated, the other southward, from somewhere near San Pedro. Reed suggests that San Pedro Hill is a "land-tied" member of the island group; it is at present largely covered with *Opuntia littoralis,* the prickly-pear so characteristic of the islands. If the islands were not connected north and south when the ancestors of the present populations mostly arrived, it is puzzling to explain why there are 21 kinds of plants and several birds which are island endemics, but occur on both the northern and southern groups. The birds may have acquired their racial characters on one island, and reached the others by flight, aided perhaps by the strong prevailing winds. But if so, why has the very distinct Santa Cruz jay, abundant on that island, never crossed to any other? There are seven kinds of birds, each confined to a single island.

Otherwise, we have to ask whether the endemics, common to the two groups of islands, may have acquired their characters independently, so that they are now, so far as we can see, alike. A. B. Howell gives a summary of the characters of the endemic birds, showing that in general they have darker markings, larger bills and heavier or longer tarsi and toes.[2] Thus it would seem that there are environmental factors tending in certain directions, which might be expected to give parallel results on different islands. In the case of plants we may note the tendency to more robust or arborescent types, and in a good many cases pale or canescent foliage. I visited Santa Catalina many years ago, but only for a very brief visit, during which I found a new moth, described by Miss A. Braun, of Cincinnati, and a new snail, which I described. The validity of the snail has been disputed by California conchologists, but it has lately been reexamined by Dr. H. A. Pilsbry, who writes me that he finds it a good subspecies.

Until the present year (1937) I had failed to find an opportunity to reach the northern islands. On July 26, I was very kindly invited by a group of the Senior Boy Scouts to accompany them to San Miguel Island, returning on August 1. I was especially glad to have this opportunity, as no wild bees had ever been collected there,[3] and there was every

[2] The local song sparrow of the Coronados Islands (*Melospiza melodia coronatorum*) is paler, with smaller bill.

[3] I have since found that E. P. Van Duzee collected a bee (Anthidium) on San Miguel many years ago.

prospect of finding other insects of interest and possibly endemic forms of various groups. It took us five and a half hours to reach the island in a fishing vessel. The sea is very choppy in the Channel (recalling the English Channel), and several of us were seasick. The botanist E. L. Greene went to San Miguel in 1886, leaving Santa Barbara on August 19, and he relates that he and four others sailed in "a very small sloop, bearing a cargo of fence boards . . . that our voyage was not without adventure will be indicated by the testimony that we did not reach the shores of San Miguel until nine days later." But going to the other extreme, Mr. George Hammond, in his red aeroplane, makes the journey in twenty minutes, having a landing place on the flat top of the island.

San Miguel has a length of about 8½ miles, with an average breadth of 2¾ miles; the area is estimated as 14 square miles. The highest points are 860 and 850 feet above sea level. The western end is about 25 miles south of the nearest mainland, but the sea between reaches a depth of over 250 fathoms. The nearest island, Santa Rosa, is only three miles away, and the channel is shallow, with a depth of only 17 fathoms.

We camped on the north side, at Cuyler's cove or harbor, the best landing place on the island. The Scout group, numbering about twenty, was in charge of Mr. John H. Leecing, Scout executive, of Santa Barbara, with the aid of Mr. J. W. Vickers, serving as cook, and Mr. M. McGregor, ready to render medical aid if necessary. The well-known efficiency of the Scouts was apparent throughout, and we all had a very good time. I climbed to the top of the island in two places, but some of the boys went all round.

The island consists largely of sand dunes, and must have been so for a very long while. Rocks of Tertiary age, near the shore, are tilted at an angle of perhaps 50 degrees, and consist of solidified sand, with occasional layers of dense stone. They were not fossiliferous where examined, but they are referred to the Eocene by Bremner in his work on the geology of San Miguel. It was in an adobe like deposit, near the top of the island, that Mr. H. S. Lester found remains of elephants. Mr. Lester, who lives in the one ranch house on the island, had for years longed to hunt elephants in Africa, and it was considered rather a joke that he eventually found them close to his home on San Miguel. The undoubted Pleistocene beds containing Elephase have not been observed to contain other fossils, but it is reasonable to hope that something else may yet be found. On the top of the island, alternating with sandy deposits, I found a caliche or travertine-like deposit, very solid but composed of sand, and standing up on this are numerous objects which look like small trunks of trees, but are actually limy concretions formed around roots which formerly occupied the ground. Some people have thought that these objects were relicts of a former forest, but this is not the case. The roots were probably those of the Lemonadeberry, *Rhus integrifolia,* a kind of sumac which once abounded on the island, so that the wood is even now used for fuel. Greene reported that as far back as 1886 he saw only two or three of these shrubs, showing feeble signs of life, but he found the wood, in one case branches 30 feet long, but not more than a foot above ground. Hoffmann, of the Santa Barbara Museum, found one shrub overhanging the ocean bluff, on April 10, 1930. But on Princess Island, at the mouth of Cuyler harbor, the plant still survives and was found by the Scouts during our expedition. Two other more or less arborescent plants were found by Greene, but have now entirely disappeared. One is Toyon, *Photinia arbutifolia,* "two stunted specimens," and the other, of

—*Scout Expedition photo*

CUYLER'S COVE, SAN MIGUEL ISLAND.

more special interest, is *Lavatera assurgentiflora,* the Malva Rosa or tree mallow. Greene tells of finding some thirty small trees of the Lavatera and also three or four depressed and straggling bushes at the very western end of the island. He commented that the San Miguel plant seemed to differ from those in cultivation; the branches much stouter, the leaves larger, the corollas of a deeper color, and the stellate pubescence of the pedicels and involucres a good deal more pronounced and conspicuous. Later, he found differences in the fruits, and many years after set up the San Miguel plant as a species, which he called *Saviniona dendroidea.* It has not been accepted by botanists, but presumably it constitutes a local subspecies, to be called *Lavatera assurgentiflora dendroidea.* Hoffmann, in all his explorations of the northern island, found Lavatera only once; four or five plants on a steep hillside above the old sheep landing, on Anacapa, on September 22, 1930.

There are thus no trees on San Miguel, if we except a fig tree (which duly bears figs) at the ranch house, where it is sheltered by the building. There has lately arisen considerable discussion concerning a project in which the Scouts were to have a part, for the "reforestation" of San Miguel. There is little reason to suppose that trees could be induced to grow in any numbers, but there are several good springs, and in the vicinity of these, especially in places more or less sheltered from the persistent high winds, it may be presumed that trees such as the lower-growing kinds of Eucalyptus would succeed. The experiment would cost little and is worth trying.

Although the list of species of plants on San Miguel shows only a small proportion of endemics, this list is swollen by the names of many plants certainly or probably introduced in recent years, and when it comes to the number of individuals, the endemics are conspicuous. The most conspicuous is the grey-green bladder-pod, *Astragalus miguelensis* of

Greene, which covers a large part of the surface. It is found on all the other northern islands (Hoffmann found it on Anacapa), but nowhere else in the world. Mr. Robert Brooks tells me that it acts on the sheep as a loco-weed, and is avoided by them. This circumstance favors the island snails, which cling to the branches of the Astragalus and would have difficulty in existing without it. These snails, a form of *Helminthoglypta ayresiana* (described from Santa Cruz) are very abundant, and have long existed on the island, as shown by their presence in the concretionary rock on the top of the island and in alluvial deposits near the shore, these surely antedating the period of human occupation. The shells are about as large as the end of one's thumb, and are light brown, with a broad white band on which is a very dark, nearly black, band. The subfossil shells are bleached white, but all show traces of the dark band. I searched long, but could find no other snails on the island; I suppose that any small forms, living on the ground, would soon be overwhelmed by the drifting sand.

Another island endemic, which occurs on San Nicolas as well as the northern islands, is the shrubby *Malacothrix implicata* of Miss Eastwood, regarded by recent writers as a variety of a mainland species. The white, daisy-like flowers are very conspicuous on the cliffs by the shore, and I found them attractive to wild bees.

The yellow-flowered *Erysimum insulare* of Greene, related to the garden wall flower, is very abundant, and noteworthy for the spreading instead of erect pods. This was described as an endemic, but has lately been taken from the list, as it occurs in some quantity in one district on the mainland. I am inclined to suppose that it is a genuine island endemic, and has been introduced on the mainland in comparatively recent times. I can even imagine that the yellow-spined prickly pear, *Opuntia littoralis,* so characteristic of the islands, owes its presence on the mainland to introduction by man; but should this be true, there would be no possibility of proving it.

The ice-plant, *Mesembryanthemum crystallinum,* is excessively abundant, and in case of need will keep animals alive in the absence of water. But Mr. Robert Brooks tells me that it acts as a purgative on the sheep, and is generally avoided by them. This plant is generally supposed to have been introduced from Africa, but Greene thought it was native, and it may be one of the group of strand plants, such as certain Convolvulaceae, which have been spread widely over the world, presumably through the agency of birds. I do not know whether the African and Californian plants have been carefully compared in the living state; as herbarium material they are almost unrecognizable.

There is much grass on the island, including a tall and very robust form of rye grass, *Elymus condensatus,* growing in the vicinity of springs, mixed with the introduced beard grass, *Polypogon monspeliensis.* Among the specimens I brought back Mrs. Agnes Chase, of Washington, recognized *Distichlis dentata* Rydberg, a plant new to the islands, and not given by Munz in his Manual of Southern California Botany, although they have a specimen at Washington which was collected in Orange County.

We did not plan to collect vertebrates, but Bruce Davis, one of the Scouts, found a specimen of the very interesting endemic salamander, *Batrachoseps pacificus,* by the spring at the landing place. It is a worm-like creature, with short legs; our specimen is darker than the descriptions indicate, at least as preserved in alcohol. Mr. Davis said that it appeared more brightly colored when alive. We also obtained a specimen of the endemic white-footed mouse, *Peromyscus maniculatus strea-*

—*Scout Expedition photo*

CONCRETIONS
RESEMBLING TRUNKS OF TREES, ON TOP OF SAN MIGUEL ISLAND.

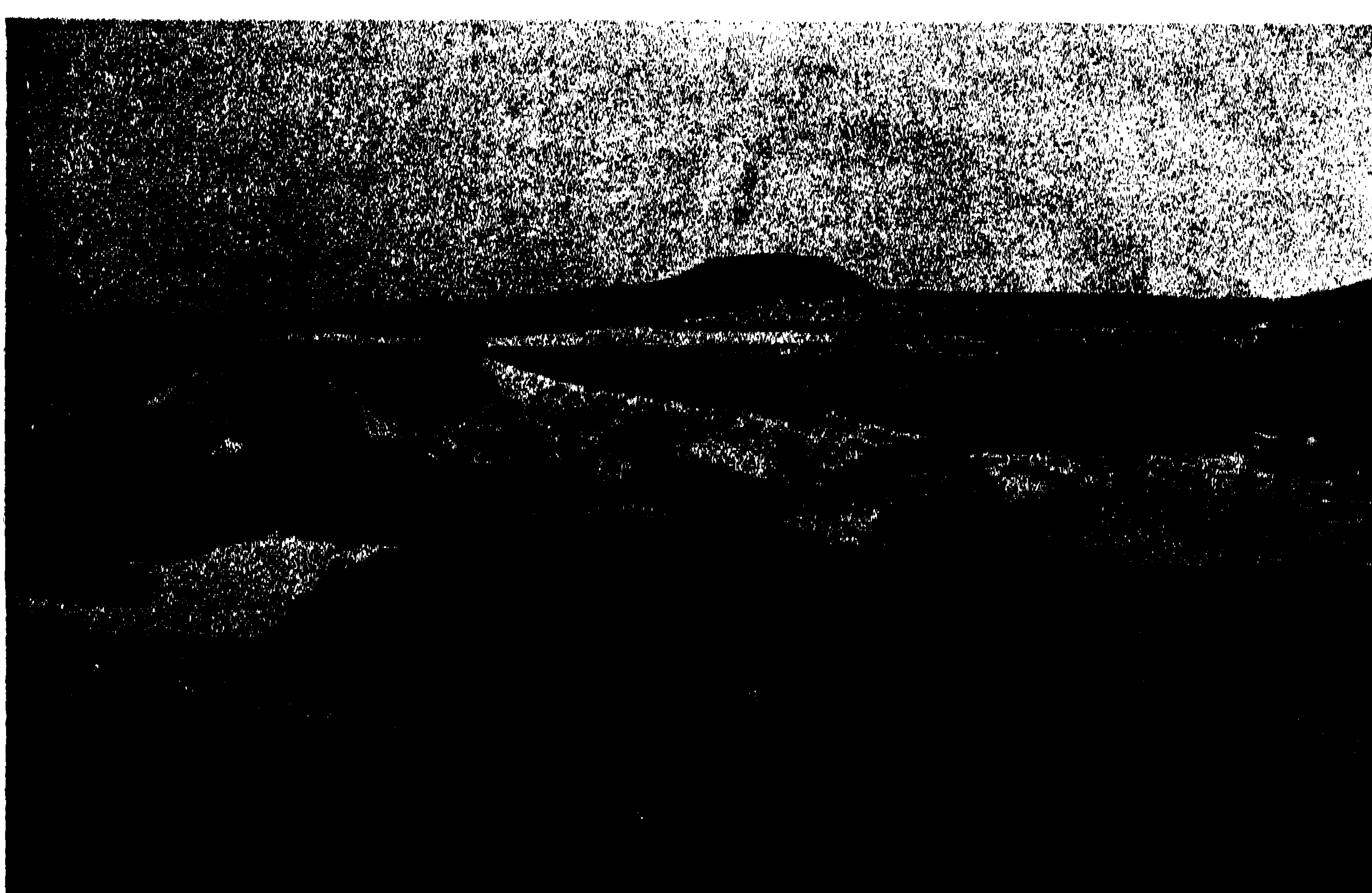
tori, which was skinned by Mr. McGregor. This was not considered important at the time, but it proved to be of unusual interest. At the Santa Barbara Museum, Mr. E. Z. Rett showed me three mice from San Miguel and a dozen from Santa Cruz, the latter belonging to the subspecies *P. m. santacruzae.* The Santa Cruz mice, about half from near the beach and half from the central part of the island, all look alike, and are very dark. The tails vary from 77 to 92 mm long. The three San Miguel mice are much paler and redder, and are smaller, the tails 66 to 71 mm. But the mouse I brought back was considerably darker than Mr. Rett's series, with a dark dorsal stripe, and the tail 78 mm. On examining the skulls, Mr. Rett found that his three mice were all very immature, while mine was adult. Thus it appears that the characters of the San Miguel race are more evident in the young mice than in the adults. The pale color is what might be expected in a sandhill species. The tracks of the mice indicated their abundance on San Miguel, and Mrs. Lester told me that some time ago they were so numerous as to amount to a plague, and they had to destroy them around the ranch house, by traps and poison, to such an extent that they were buried in trenches. Hearing this, I lamented the waste of so many specimens of this endemic race, hardly represented in museums. We hope to see a good series secured for the Santa Barbara Museum.

The insects obtained will be reported on later.[4] Among the smaller insects, I expect to find few endemics, as they can be blown from the mainland by the strong prevailing winds. Collections made in the air by means of aeroplanes have demonstrated that many small insects are thus transported. Spiders, when young, can travel on their gossamer

[4] I have since worked up the bees. I find I collected sixteen species, of which seven are new species, and five others new races of mainland species.

threads. Many years ago, the well-known zoologist Eisen collected ten species of spiders on Santa Rosa, and these were recorded in 1904 by Dr. N. Banks. Two of them were new species and peculiar to Santa Rosa, so far as the records then showed. Of butterflies, I found on San Miguel only two species, a Lycaenid or "blue," and a small yellow skipper which I failed to catch. There are probably others, but they can not be nearly so numerous as on Santa Catalina, where 27 species were taken by Don Meadows. The few moths taken were pale colored, like the sandhill species of other countries. A kind of mealy-bug, perhaps new, was found on *Astragalus miguelensis*. The females can not fly, and the males fly feebly, but the young larvae can be transported on the feet of birds. We found cricket-like orthoptera, entirely wingless, of the genera Stenopelmatus and Ceuthophilus, and these may well prove to be endemic.

Mr. M. E. Rodehaver very kindly took several of us over to Princess Island, a small island at the entrance to the bay. It is commonly called Prince or Prince's Island, and is so marked on maps, but Hoffmann, in his herbarium, always wrote Princess. Mr. Brooks states that the name was due to a legend of an Indian "princess," whose conduct was not approved of, and who was transported to the island, where she would soon have perished. Princess Island has been chiefly known as the breeding place of innumerable sea birds, especially pelicans (*Pelicanus californicus*), cormorants and gulls. It is quite steep, and so covered with ice-plant that it is slippery and hard to climb. There is a good deal of prickly-pears (*Opuntia littoralis*), but the common Astragalus and Erysimum of the main island appear to be entirely absent. There are no snails, so far as I could discover. The boys found Rhus, as already mentioned, and on the top blackberry



—*Scout Expedition photo*

THE TOP OF SAN MIGUEL ISLAND

WITH SHIFTING SAND DUNES, LARGELY COVERED WITH ASTRAGALUS MIGUELENSIS.

(*Rubus vitifolius*), which had previously been collected there by Hoffmann. A single bee (Agapostemon) was found in a spider's web.

We had no opportunity to make any study of the marine mammals, but seals (*Phoca richardii geronimensis*) were seen about Princess Island, and many dead ones were found on the shores of the main island, shot by the fishermen. In addition to the common seal, no less than four different marine mammals (exclusive of Cetacea) have been found about the islands, namely, the Guadalupe fur seal, the northern elephant seal, the Steller sealion and the California sealion. The first of these has not been seen for some years. Mr. D. B. Rogers reports remains of the Guadalupe fur seal and elephant seal in Indian middens. The kitchen middens of the ancient Indians are very conspicuous on San Miguel, consisting mainly of great heaps of shells of the edible mussel (Mytilus), with numerous red abalones. Rogers (1929) recognizes three successive types of aboriginal inhabitants on the mainland of Santa Barbara County. The first or earliest, called the Oak Grove People, offer remains in great abundance, but of such fragmentary nature and so imbedded in a semi-fossil state in a strong matrix that their recovery and restoration are extremely difficult. The second group is called the Hunting People, and the third the Canalina People. The latter are supposed to have been in full possession of the entire region as early as 1000 A. D., and these are the people found by J. R. Cabrillo when he discovered the islands in 1542. The matrix in which the Oak Grove remains occur may possibly be contemporaneous with and similar to the dense deposit, containing snail shells, on the top of San Miguel.[5] On San Miguel, it appears to be definitely older than any of the Indian remains, but this should be expected, as according to Rogers the first two types of inhabitants never reached the islands. It was the Canalina type, presumably coming from the north, who had boats, and colonized the islands.

The recorded birds of San Miguel appear to number only 41 kinds, as against 149 from Santa Cruz. This may be partly due to the fact that Santa Cruz has been more frequently visited by collectors, but in the main it is an expression of the comparative poverty of the island, with a comparatively limited fauna and flora. Mr. Brooks states that the white-headed eagles (*Haliaetus leucocephalus*) do attack the sheep, but are not nearly so injurious as the ravens (*Corvus corax sinuatus*), which prey on the young lambs as they are born. A form of song-sparrow (*Melospiza melodia micronyx* of Grinnell) is peculiar to San Miguel.

[5] Mr. Rogers thinks that this is not the case. He agrees with me that this deposit appears to be older than the middens on the island and must antedate the coming of the Indians. Bremner, in his "Geology of San Miguel Island" (published by the Santa Barbara Museum, 1933) has a very good figure of the deposit, marked "Sand cemented with calcium carbonate, preserving the forms of roots and stumps of vegetation destroyed in the past century," but he gives no reasons for assigning such a recent date. The shells in the middens have not disintegrated, and the calcium carbonate is probably derived from minute fragments of shells in the sand.

—*Bachrach*

PROFESSOR WESLEY C. MITCHELL

PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE THIRD INDIANAPOLIS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND ASSOCIATED SOCIETIES

THE American Association for the Advancement of Science has met three times at Indianapolis. Its first meeting in that city occurred in August, 1871, when the association was but twenty-three years old. At the opening of that meeting there were only 528 members, but when it closed the enrolment had increased to 668, which is ample evidence of a successful meeting for those times. The success of that first Indianapolis meeting is shown in another way by recalling that the famous botanist, Asa Gray, of Harvard University, was president and that papers were read by such men as Alexander Agassiz, Edward D. Cope, James Hall, Joseph Henry and Richard Owen. The second Indianapolis meeting was held after an interval of nineteen years, in August, 1890. At that time the association president was George L. Goodale, who had succeeded Gray as professor of botany at Harvard, and the roll of members then included 1,935 names. And now, after an additional interval of nearly half a century, we are recording the very successful completion of the third Indianapolis meeting, which opened on Monday, December 27, 1937, and closed on the following Saturday. This was the 101st meeting of the association.

The total association enrolment is now much more than twenty-five times as great as it was at the time of the first Indianapolis meeting. But the organization of the association has been altered in the intervening period, so that it now represents not only its own actually enrolled members—whose dues contribute directly to its support—but also the many tens of thousands who are not individual members but who are members of the many officially associated scientific societies that aid and cooperate with the association in the various phases of its activities. Besides many sessions of the association and its sections this meeting included sessions of over forty autonomous societies, and the total attendance was over 4,500.

Large numbers of people not professionally engaged in science were in attendance at some of the sessions, for the association now aims to facilitate the spread of scientific knowledge and appreciation among all thinking people, and its annual meetings have become increasingly attractive and interesting to the general public as well as to professional men and women of science. Indeed, the association has become much more than a technical or professional organization, and every one is invited to join with it in rendering real service not only to science and its devotees but also to society as a whole. Realizing that still further increase in membership is needed to render the association increasingly effective, the council voted at Indianapolis to remit the entrance fee to all who may enroll in 1938.

The daily press naturally constitutes the main channel through which the public may become acquainted with the diverse array of discoveries and new ideas brought forward at these great meetings, and one of the most significant developments of recent years has been a continual improvement in the manner in which the newspapers report the meetings. As recently as fifteen years ago the press generally gave only cursory attention to science and scientific conventions, but all the great dailies have come to a full appreciation of the importance of science news, and many of our most able news writers now devote themselves largely to the writing of news of that kind. The press room at the third Indianapolis meeting was a very busy cen-

JORDAN HALL, BUTLER UNIVERSITY

WHERE THE MATHEMATICIANS AND THE SECTION ON ECONOMIC AND SOCIAL SCIENCES HELD THEIR MEETINGS.

ter, from which hundreds of science notes and science stories were sent out, to appear promptly as current news in newspapers throughout this country and abroad. This meeting was more efficiently reported in the daily press than any earlier meeting, and the general public was able to follow it in news reports from day to day throughout the week. This was due to the tireless labors of many expert science reporters, who have recently organized the National Association of Science Writers to facilitate their work. The cordial cooperation of that organization with the American Association for the Advancement of Science is of very great significance in promoting increasingly wide-spread interest in things scientific.

The General Program of this meeting, which is a book of 273 pages, announces the presentation of over 1,650 papers and addresses by more than 1,800 authors—joint or cooperative authorship appears to become more frequent as scientific knowledge advances with the years. There were 225 separate sessions for the reading of papers and these required the use of more than 50 rooms. There were 36 society dinners and luncheons. Most of the sessions were held in centrally located hotels, within a radius of five blocks, but those of the mathematicians were accommodated at Butler University, six miles away, while the zoologists met at Indiana University Medical School, about a mile and a quarter distant.

Science now influences our daily lives in so many and in such intricate ways that thoughtful minds are turning more and more to the study of its broad relations to society and human welfare. The association has planned a series of conferences on these relations, the first of which was an outstanding feature of this Indianapolis meeting. It occupied five late-afternoon sessions of the organization as a whole, extending from Monday to Friday, its general title being "Fundamental Resources as Affected by Science." Nine eminent speakers took part, with subjects that ranged widely over the field of science—including general economics, agricultural, forest and mineral resources, resources of power and capital, man power and human resources, business organization and research laboratories.

Notable contributions to our rapidly growing knowledge of the chemistry of life were presented in a symposium of six invited papers, arranged by the association's section on chemistry. These dealt with surface films and their peculiar phenomena, knowledge of which throws much light on many basic problems of cell physiology. The leader of this symposium was Dr. Irving Langmuir, of the Research Department of the General Electric Company, who has devoted himself to the study of surface chemistry for many years. Dr. Langmuir also gave the sixteenth annual Sigma Xi lecture, arranged jointly by the American Association and the Society of Sigma Xi. Presented at an evening session for the general public, it too was on the biological applications of surface chemistry.

Another evening session for the general public was devoted to the third annual Phi Beta Kappa lecture, under the joint auspices of the American Association and the United Chapters of Phi Beta Kappa. This interesting and graciously humorous address, on "Shakespeare and the Critics," was given by our most eminent Shakespearean scholar, Dr. George Lyman Kittredge, of Harvard University. It was preceded by Tschaikowsky's Fourth Symphony, played by the Indianapolis Symphony Orchestra.

A third evening lecture, to which the public as well as professional science workers were invited, was delivered by Dr. Thomas Parran, Jr., surgeon-general of the U. S. Bureau of the Public Health Service, who spoke on the timely topic, "Syphilis as a Public Health Problem."

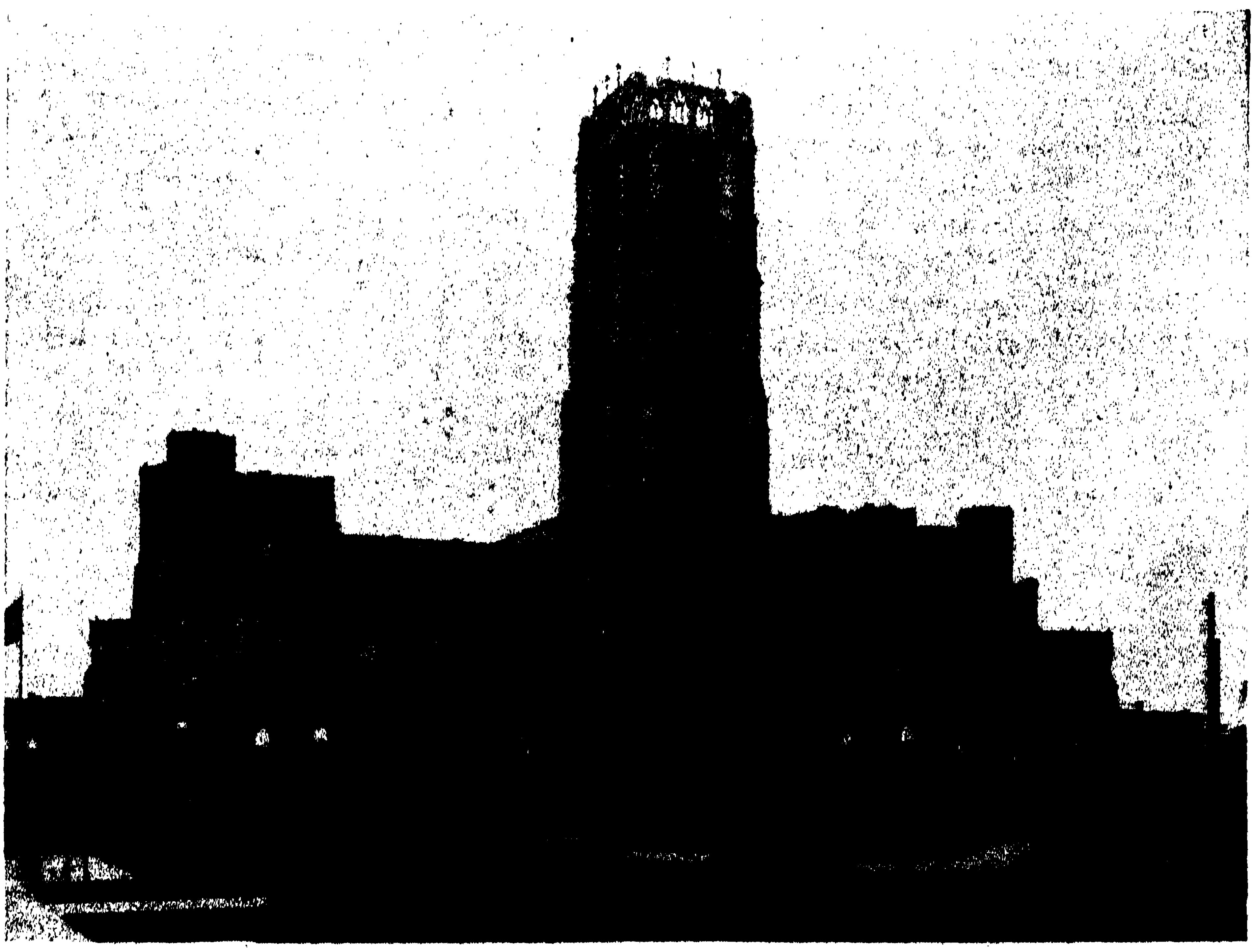
A late-afternoon lecture by the vice-president for the Section on Medical Sci-

ences, Dr. Esmond R. Long, director of the Henry Phipps Institute, of Philadelphia, was well attended. Dr. Long spoke on "Leprosy and Allied Mycobacterial Infections."

At the annual luncheon of the American Science Teachers' Association, Dr. George D. Birkhoff, eminent mathematician of Harvard University and president of the American Association for the Advancement of Science for 1937, presented interesting and even startling results of his long study of possible ways and means by which esthetic values, such as those of the graphic arts, music and poetry, may be quantitatively compared and appraised.

The address of the retiring president of the American Association, who had been president in 1936, was given on Monday evening by Dr. Edwin G. Conklin, professor emeritus of zoology in Princeton University and executive secretary of the American Philosophical Society. His analytical but at the same time plain and scholarly lecture, on the relations between science and ethics must prove helpful and encouraging to all who are deeply concerned about the fundamental place of science in human life, in education and in the advance of civilization. A new note was sounded when he urged all devotees of science to take active part in maintaining and increasing freedom of individual thought and expression. Dr. Conklin's address was published in *Science,* which is the official journal of the American Association, for December 31, 1937.

At the close of this meeting was announced the fifteenth award of the American Association's annual prize of one thousand dollars. As will be remembered, funds for this prize have been given by a member who wishes to aid and encourage younger investigators in an im-



SCOTTISH RITE CATHEDRAL

personal and anonymous way. This award is made each year to the author of a noteworthy paper presented at the winter meeting of the association and its associated societies. The recipient this year is Dr. Philip R. White, of the Rockefeller Institute, Princeton, New Jersey. After attaining the A.B. degree of the University of Montana in 1922, Dr. White received the Ph.D. degree of the Johns Hopkins University in 1928, and he was afterwards a fellow of the National Research Council, working at the Boyce Thompson Institute for Plant Research as well as abroad. He has contributed much to advance our knowledge of the nutritional physiology of excised roots. In the paper for which this award was made, which was presented before the Physiological Section of the Botanical Society of America, Dr. White reported his experimental demonstration, in excised tomato roots, of maintained secretion pressures above six atmospheres—a magnitude several times as great as the sap pressures, or bleeding pressures, previously known to occur in plant roots. His experimental technique is new and ingenious, his report is a noteworthy contribution to our still hazy knowledge of cell secretion, and his findings in this field may have important bearings on some phases of the perennially discussed questions concerning the hydrodynamics of the rise of sap in plants.

At Indianapolis the American Association's annual science exhibition, which is an important and specially enjoyable feature of each winter meeting, included no less than seventy separate exhibits of scientific apparatus, methods and results. Recent developments in the study of cosmic rays were shown by the well-known students of this physical field, Dr. Arthur H. Compton and Dr. Robert A. Millikan, and by the National Bureau of Standards. A striking painting of the colorful corona of the solar eclipse of June 8, 1937, as seen from the mid-Pacific, was part of an interesting exhibit by the National Geographic Society. The American Medical Association exhibited a series of alleged curative but really weird and worthless contraptions of pseudo-science that have been foisted upon credulous people. An exhibit of the U. S. Public Health Service showed treatments for various forms of syphilis. The Indiana Academy of Science occupied three booths to show the history and accomplishments of the academy itself and the interesting science work of high-school students in its associated Junior Academy. Among the less striking but really most helpful features of this exhibition was a comprehensive library of recently published and standard books on a great variety of scientific subjects. An attractive exhibit showing the historical development and the natural resources of the Commonwealth of Virginia recalled the fact that next winter's meeting of the American Association is to be held at Richmond.

For the first time in many years, the newly elected president of the American Association, for 1938, represents the social and economic sciences, which constitute the province of Section K, and this election reflects a notable trend of these times. President Wesley C. Mitchell, professor of economics in Columbia University, is most eminent in his field. As shown by his teaching and by his many well-known publications, his work has been truly scientific as well as scholarly—in a field where the scientific method has often been neglected. He has been a leader in the development of American economics, holding important positions in a number of universities and government institutions. For the year 1933 he was vice-president of the association and chairman of its Section K.

The next summer meeting of the American Association and associated societies is to be held at Ottawa, Canada, from June 27 to July 2, 1938. The next winter meeting will occur at Richmond, Virginia, from December 27 to 31, 1938.

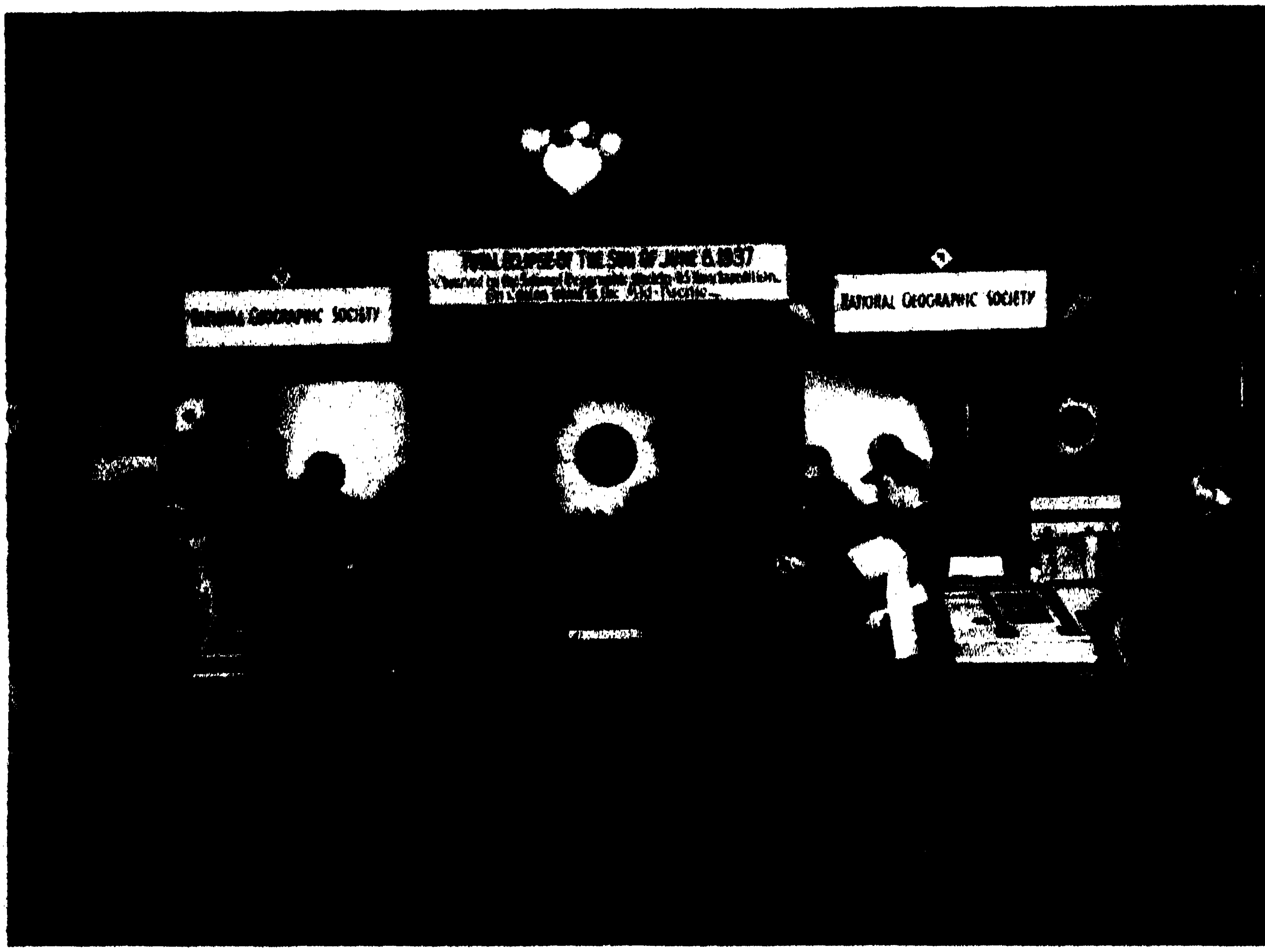


EXHIBIT OF THE NATIONAL GEOGRAPHIC SOCIETY

RESULTS OF THE NATIONAL GEOGRAPHIC SOCIETY-U. S. NAVY EXPEDITION, WHICH OBSERVED THE TOTAL SOLAR ECLIPSE OF JUNE 8, 1937, ON CANTON ISLAND IN THE MID-PACIFIC, WERE DISPLAYED WITH ENLARGED PHOTOGRAPHS, TRANSPARENCIES AND DIAGRAMS. THE CENTRAL FEATURE WAS AN OIL PAINTING OF THE ECLIPSE BY CHARLES BITTINGER, OF WASHINGTON, D. C. A 14-FOOT CAMERA DESIGNED BY DR. IRVINE C. GARDNER, OF THE NATIONAL BUREAU OF STANDARDS, AND A POLARIZATION CAMERA USED BY DR. F. K. RICHTMYER, OF CORNELL UNIVERSITY, ALSO WERE ON EXHIBITION. DR. S. A. MITCHELL, DIRECTOR OF THE UNIVERSITY OF VIRGINIA OBSERVATORY, WAS SCIENTIFIC LEADER AND CAPTAIN J. F. HELLWEG, SUPERINTENDENT OF THE U. S. NAVAL OBSERVATORY, WAS IN CHARGE OF THE NAVY'S PARTICIPATION.

All who attended the third Indianapolis meeting will long remember it with great pleasure, not only because of its general excellence with regard to the regular features of the American Association's winter conventions but also because of the very fine services so freely given by the Indiana Committee for the meeting, whose chairman was Dr. Stanley Coulter, eminent biologist of Purdue University, and because of the delightful hospitality accorded to visitors by the institutions and people of the state and of the city.

Austin H. Clark
Burton E. Livingston

THE PRESIDENT OF THE ASSOCIATION

For the first time since Carroll D. Wright was president in 1903 the American Association for the Advancement of Science has chosen for president a man preeminent in the science of economics. As an economist, Professor Wesley C. Mitchell, of Columbia University, has been an acknowledged leader for over a quarter of a century.

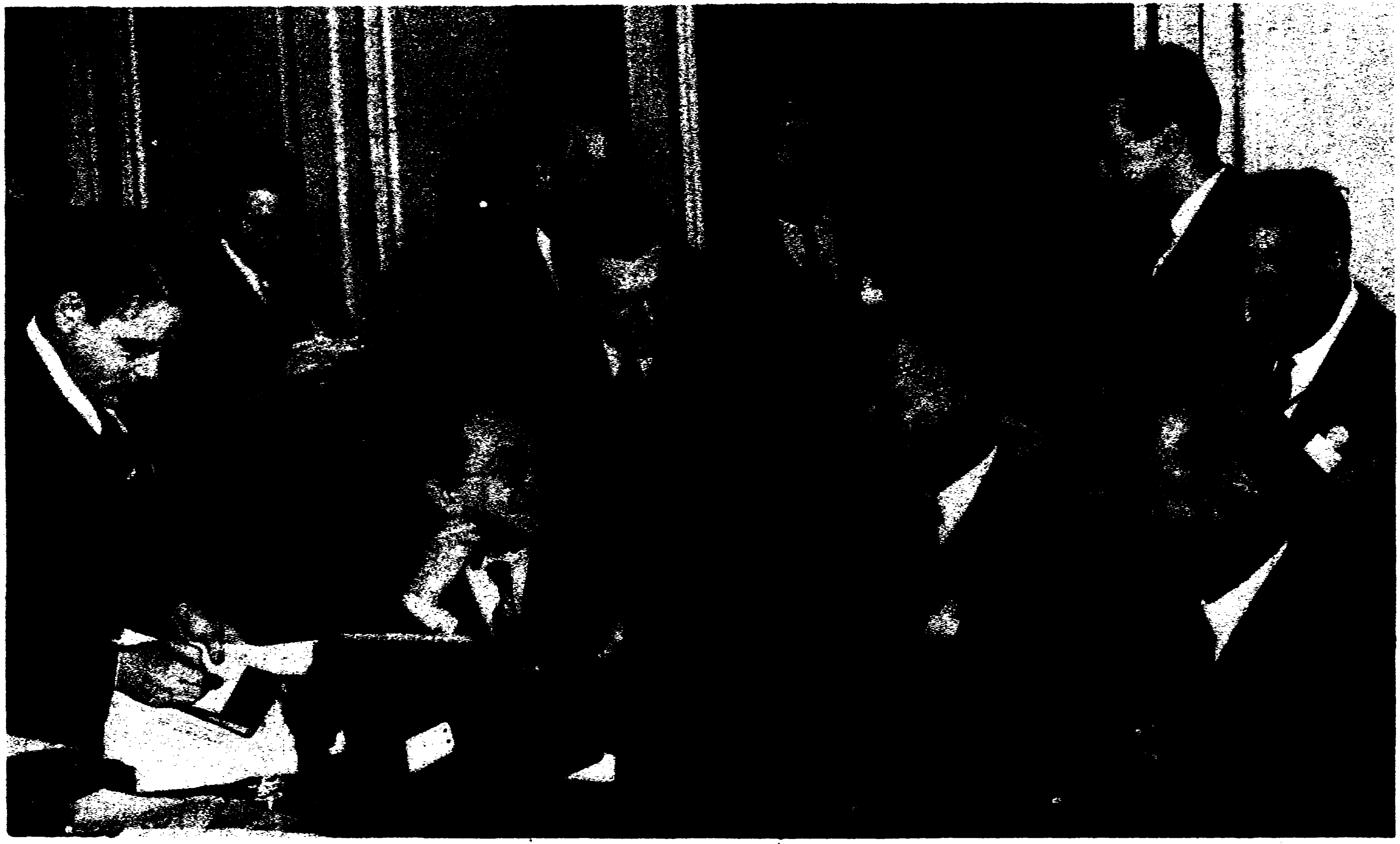
He was born in Rushville, Illinois, on

August 5, 1874. In 1892 he had the good fortune to be a member of the first class of the pioneering University of Chicago, where he felt directly the stimulating influence of Thorstein Veblen and John Dewey. As Armour-Crane traveling fellow of the University of Chicago, he studied at Halle and Vienna in 1897–1898, and received the degree of Ph.D. summa cum laude from the University of Chicago the following year.

Professor Mitchell's career in teaching has included the universities of Chicago, California, Harvard and finally Columbia, all of which have attested to the character of his work by awarding him honorary doctorates. In addition he was George Eastman Visiting Professor at Oxford in 1931–1932. At home he has been further honored: with the presidency of the American Economic Association, the American Statistical Association and the Academy of Political Science; with the chairmanship of the Social Science Research Council and the President's Research Committee on Social Trends; with membership in the American Philosophical Society, the American Academy of Arts and Sciences and the Council of the American Geographical

EXHIBIT OF PROFESSOR HAROLD C. UREY

PROFESSOR UREY, OF COLUMBIA UNIVERSITY, IS SHOWN WITH HIS EXHIBIT OF SAMPLES OF WATER WHICH HAVE AN INCREASED CONCENTRATION OF THE O^{18} ISOTOPE APPROXIMATELY FOUR AND ONE HALF TIMES THAT OF NATURAL WATER. THERE ARE ALSO SAMPLES OF AMMONIUM CHLORIDE WHOSE NITROGEN CONTAINS AS HIGH AS 2.5 PER CENT. OF N^{15}, BEING A SIX AND ONE HALF FOLD INCREASED CONCENTRATION OF THIS ISOTOPE. THESE SAMPLES HAVE BEEN PREPARED BY THE DISTILLATION OF WATER AND BY A CHEMICAL EXCHANGE REACTION BETWEEN AMMONIUM ION AND AMMONIA GAS. THERE ARE DIAGRAMS ILLUSTRATING THE METHOD USED, AND EXHIBITS SHOWING THE METHOD OF THE RESEARCHES AND THE PROGRESS MADE IN USING THESE MATERIALS.



—*Courtesy of the Indianapolis Star*

PRESIDENT BIRKHOFF AND MEMBERS OF THE NATIONAL ASSOCIATION OF SCIENCE WRITERS

LEFT TO RIGHT: STEPHEN J. McDONOUGH, ASSOCIATED PRESS; HOWARD W. BLAKESLEE, ASSOCIATED PRESS; WILLIAM L. LAURENCE, *New York Times* (AT TYPEWRITER); ALLEN SHOENFIELD, *Detroit News* (DIRECTLY ABOVE); JAMES C. LEARY, *Chicago Daily News* (FACE PARTLY CONCEALED); DAVID DIETZ, SCRIPPS-HOWARD NEWSPAPERS; PHILIP KINSLEY, *Chicago Tribune*; PRESIDENT GEORGE D. BIRKHOFF; STEVEN M. SPENCER, *Philadelphia Evening Bulletin* (STANDING); JOHN J. O'NEILL, *New York Herald-Tribune* (SEATED); GOBIND BEHARI LAL, HEARST NEWSPAPERS.

Society; and with the Gold Medal of the National Institute of Social Sciences. Abroad he has been made an honorary fellow of the Royal Statistical Society, corresponding member of the Manchester Statistical Society and a member of the Institut International de Statistique.

In the councils of state, in times of stress, Professor Mitchell directed scholarly research. In 1915, he prepared "The Making and Using of Index Numbers" (revised in 1921) which has become a basic work on the subject. During the world war, he was chief of the price section of the War Industries Board, where he also acted as editor and collaborator in "The History of Prices During the War" and "International Price Comparisons." In more recent years, as a member of the National Planning Board, and its successor, the National Resources Committee, Professor Mitchell helped to formulate policies of research leading to a more orderly functioning of the national economy.

Professor Mitchell's numerous works, written in a stately English prose, cover a wide range of interests. Out of his doctoral dissertation, "The History of the Legal Tender Acts of 1862 and 1863" grew the definitive study on "A History of the Greenbacks." This was followed five years later by a similarly comprehensive work, "Gold, Prices and Wages under the Greenback Standard."

In 1913, Professor Mitchell published his epoch-making study, "Business Cycles," which has not only formed the basis for most of the important subsequent investigations in the field, but has been the most potent factor in calling an obscure and neglected field to the center of attention. Using the simple statistical methods then available with insight, he so formulated and investigated the problem that to-day the economic and social order is being successfully analyzed with the phases of the business cycle as guiding factors. In 1927, he published the first volume of his new study of the subject, "Business Cycles, the Problem and its Setting."

But "Business Cycles" has been merely one aspect of Professor Mitchell's successful endeavors to formulate significant problems in such a fashion that the economic and social order might be susceptible to quantitative analysis and brought within the realm of scientific inquiry. To his influence, therefore, is due in good part the importance of and the attention to statistical analysis in the social sciences. Along the same line, Professor Mitchell has, as the director of research in the National Bureau of Economic Research, and as one of its investigators, guided the bureau's distinguished studies in such subjects as national income, prices, production, unemployment and wages.

Furthermore, Professor Mitchell has led the movement to encourage scientists, regardless of their disciplines or specialties, to act together in the analysis of specific problems or more general trends. One outgrowth of his efforts has been the monumental studies, "Recent Economic Changes and Recent Social Trends." Finally, his addresses and essays, of which the most important have been recently republished in "The Backward Art of Spending Money and Other Essays," have provoked inquiry along new paths.

Throughout, the principal aim of Professor Mitchell's work has been and is, to further research. No serious, aspiring scholar could have a better guide, for he is always encouraging any new viewpoint, be it even radically opposed to his own, and he is ever willing to give shrewd, incisive criticisms and suggestions to the honest, independent inquirer who shows a desire and capacity to profit from the advice. With his own high example of carefulness, integrity and tolerance before them, it is not to be wondered at that not a few of his students have attained distinction.

JOSEPH DORFMAN

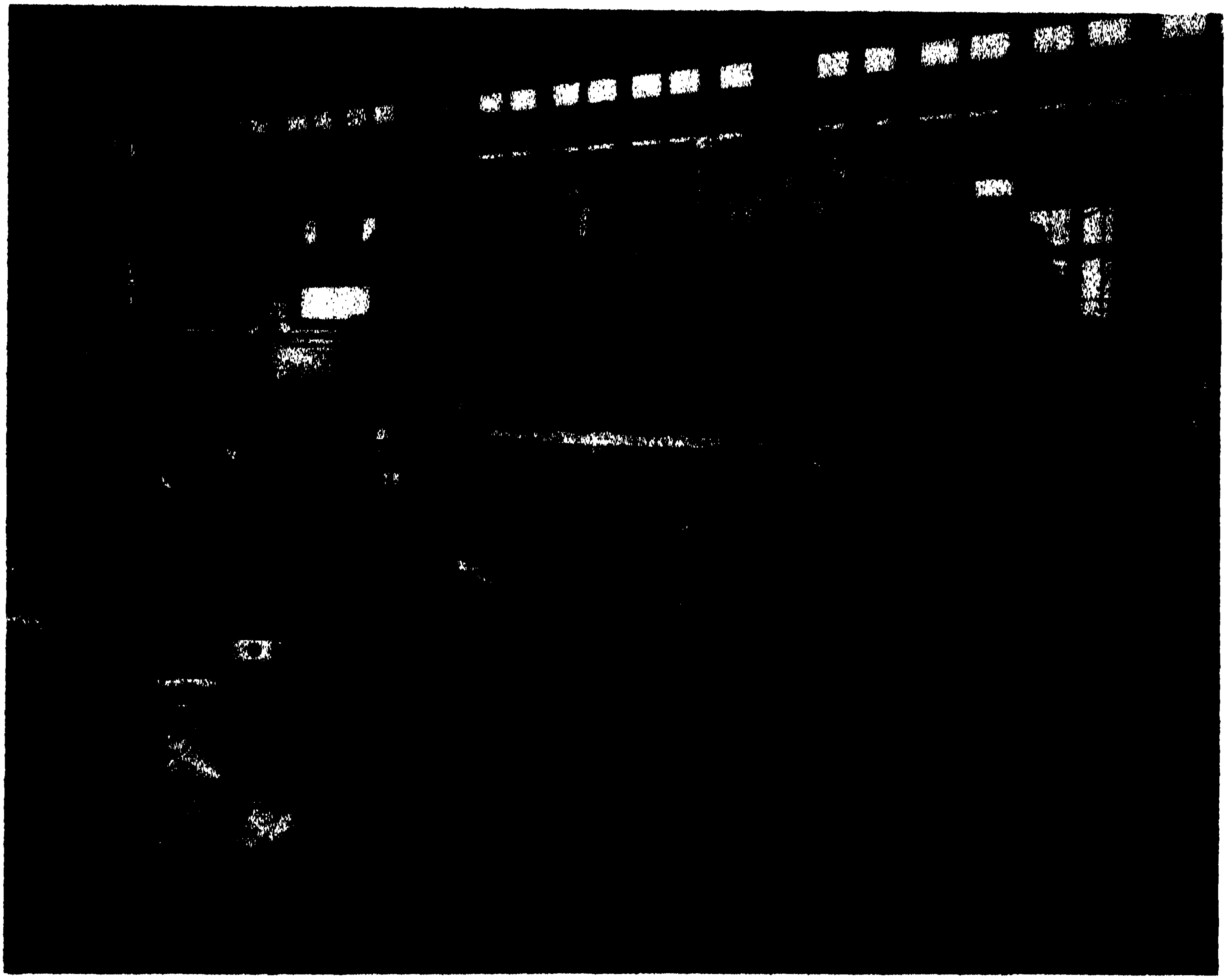
THE CYCLOTRON

NUCLEAR physics is that branch of science in which investigators study the structure and properties of the smallest particles of matter—the nuclei of the atoms themselves. This is accomplished by disintegrating the atomic nuclei with very small high energy projectiles such as protons, deuterons and neutrons. For this purpose the equipment needed is larger and more complicated than that required in almost any other branch of physics. Of all the heavy and complicated tools used by the physicist in delving into this sub-microscopic world of the atomic nucleus the heaviest and most complicated and one of the most useful is the cyclotron or "magnetic resonance accelerator" developed by Professor Ernest O. Lawrence and Dr. M. Stanley Livingston at the University of California.

The cyclotron produces ionic projectiles (atomic nuclei) with energies equal to those which would be obtained by electrical potentials of many millions of volts, but without actually developing these high potentials. The ions are accelerated in hundreds of small steps, each equal to only a few thousand volts, until they acquire a final energy of 5, 6 or 7 million electron volts. This is accomplished by keeping the ions in "resonance" with a high frequency electric field, so that with each reversal of electric potential the ions acquire an increment of energy. The ions are forced to travel in circular paths by the application of a powerful magnetic field produced by an electromagnet. As they revolve they pass between the two semicircular high frequency electrodes, each time just in phase with the alternating electric field, so that in each passage they experience an acceleration. With each increase in energy the ions revolve in larger circles in the magnetic field until they finally fly out tangentially with maximum energy. The layman might visualize this as similar to the method of setting a swing into motion by a succession of small pushes timed to the natural period of the swing. The electrical engineer would be able to compare the cyclotron to a single-phase induction motor, but a motor in which the armature is replaced by the circulating ions and operated by alternating electric fields rather than magnetic fields.

The evacuated chamber in which the high frequency electrodes are mounted and inside of which the ions are accelerated is of a flat cylindrical shape, about 40 inches in diameter and 5 inches high in the larger installations. The electromagnet to maintain a magnetic field of some 18,000 gauss strength throughout this chamber is larger than any magnet ever built for any other purpose. The solid iron core and frame stands some 8 feet high, is 12 to 15 feet broad and weighs nearly a hundred tons, easily dominating the laboratory. The high frequency potentials applied to the electrodes are generated by oscillator tubes equal in power output to a large radio broadcast station, but operating at shorter wave-lengths (15 to 20 meters). This involves an impressive array of transformers, kenotrons and generators. The vacuum pumps, motor-generator sets, water-cooling pipes and electrical leads to the chamber, etc., contribute to the impression of complexity of the apparatus.

The cyclotron is only the gun from which nuclear projectiles are fired. In order to study the disintegrations which result when a beam of the high energy particles are directed on targets extremely sensitive instruments of various kinds are used. These include ionization chambers, vacuum tube amplifiers, cloud chambers and many other types of apparatus. Each represents the ultimate



PROFESSOR ERNEST O. LAWRENCE AND DR. M. STANLEY LIVINGSTON
BESIDE THE ELECTROMAGNET OF THE FIVE-MILLION VOLT CYCLOTRON AT THE UNIVERSITY OF CALIFORNIA, JUST PREVIOUS TO ITS ASSEMBLY.

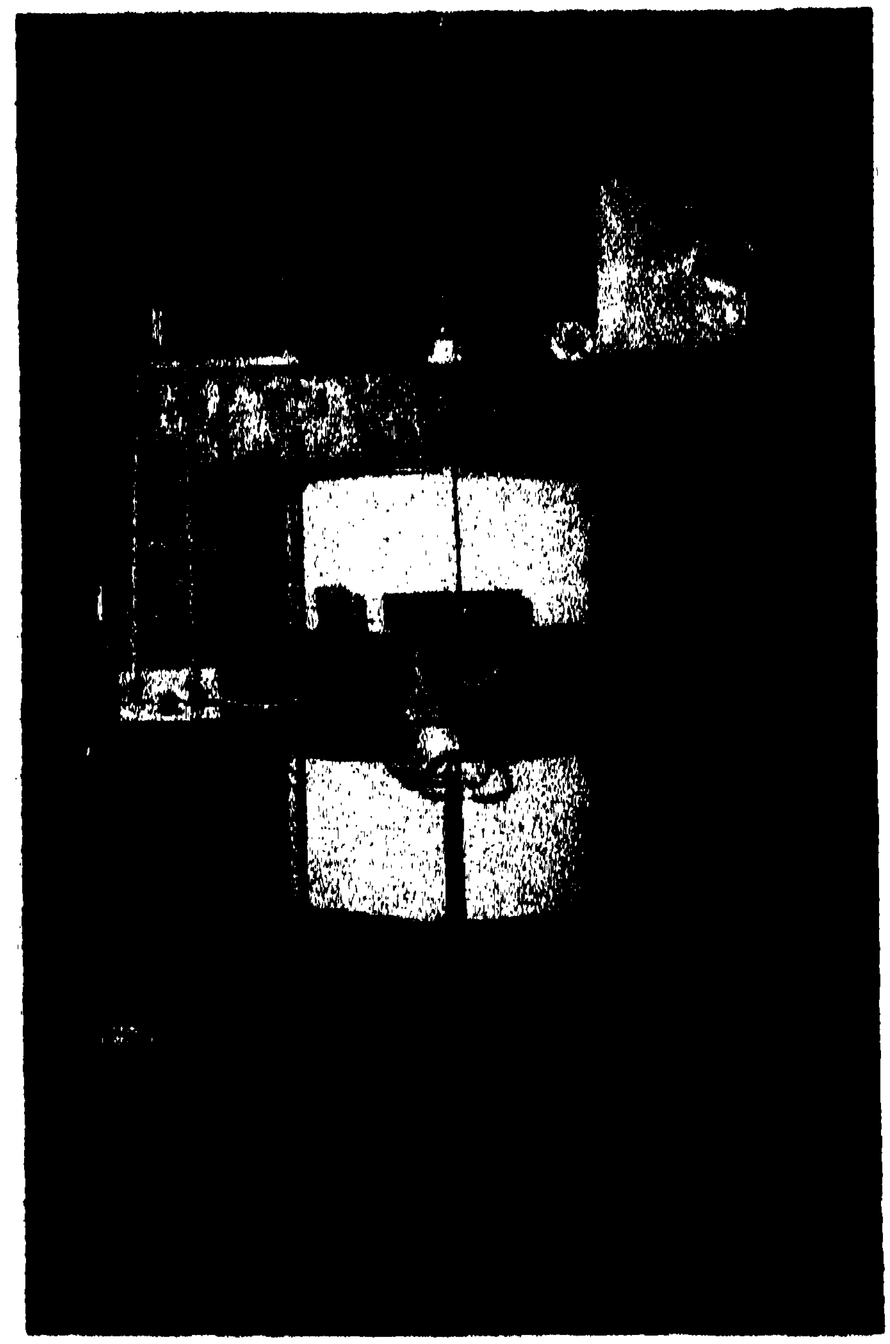
in the development of sensitive instruments for recording the products of nuclear disintegration.

Among the large number of valuable developments in the field of nuclear physics, in which the cyclotron has played a considerable part, the two most important are the production of induced radioactivities and of neutrons. Practically all the known chemical elements can be disintegrated and transmuted into different chemical elements by using one or more of the various nuclear projectiles now available. Among the products of these disintegrations are found hundreds of unstable elements, chemically equivalent to known stable elements but consisting of previously unknown isotopes. These decay in a manner similar to radium, but with much shorter life periods. In the decay process they give off high energy electrons, positrons or gamma rays. The cyclotron far exceeds other types of apparatus in the amount of such radioactive material that can be produced; already intensities nearly comparable to those from the natural radioactive elements such as radium and thorium can be obtained. Radioactive sodium (Na^{24}) has been used in preliminary experiments as a substitute for radium in biological and medical experiments. Many laboratories throughout the world are now engaged in other experiments, in which the radioactive materials are used

as indicators of chemical and biological changes. Thus a new and valuable tool has been given to other fields of science.

The cyclotron is also preeminent in the production of neutrons, those relatively newly discovered and mysterious components of matter. Neutrons penetrate the densest of metals with ease, but are strongly absorbed by the light atoms such as constitute the human body. In addition to their many interesting physical properties they seem to have the property of killing tumorous and cancerous cells, which has heretofore been the province of the x-ray and the gamma ray. It may be hoped that they will prove to be even more beneficial.

Nuclear physics is a young and rapidly growing science. A score or more of laboratories are building cyclotrons for further studies of the atomic nucleus and for other applications of the new techniques to chemical, biological and medical problems. The Radiation Laboratory of the University of California has become a training school for cyclotron engineers, and at present more than thirty physicists and biologists are engaged in learning the techniques of the cyclotron under the direction of Professor Lawrence. In several laboratories cyclotrons are already completed and in operation, at the Universities of Michigan, Illinois, Rochester, Princeton and at Cornell. Several prominent foreign scientists have migrated to Berkeley to get first-hand information about the cyclotron, and have returned to their countries to make installations. Several of the cyclotrons now in construction are capable of producing ionic projectiles with energies of over 10 million electron volts. This is far in excess of the energies possible with other types of high voltage apparatus, which are limited by the insulation problem for such high potentials. The chief advantage of the cyclotron lies in the fact that it does not require such high potentials and so is relatively simple and safe to operate.



THE TWO-MILLION VOLT CYCLOTRON
BUILT BY DR. LIVINGSTON AT CORNELL UNIVERSITY. ACCELERATING CHAMBER IN PLACE BETWEEN THE POLES OF THE ELECTROMAGNET.

ACCELERATING CHAMBER
OF THE FIVE-MILLION VOLT CYCLOTRON AT THE UNIVERSITY OF CALIFORNIA WITH COVER PLATE REMOVED.

It is a paradox of physics that the largest and most powerful apparatus is required to study that smallest of physical entities, the atomic nucleus.

M. STANLEY LIVINGSTON

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CORE SAMPLES OF THE OCEAN BOTTOM AND THEIR SIGNIFICANCE

By Dr. CHARLES SNOWDEN PIGGOT
GEOPHYSICAL LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

Foreword

SEVERAL years ago I determined the radium in a number of ocean-bottom samples, secured during the last cruise of the non-magnetic ship *Carnegie*, by means of the "telegraph snapper." These samples contained several times as much radium as the rocks with which I was then working, and I became interested in whether or not this radium concentration continued below the surface. This led to the development of the apparatus illustrated here, whose principle of operation, as compared with that of the telegraph snapper, is shown in Fig. 1. The telegraph snapper merely takes a small bite out of the surface of the bottom, and destroys the stratification in so doing. This apparatus drives a tube through many strata and brings up a sample whose parts remain in their original relation with respect to one another.

Introduction

Nearly three quarters of the surface of the earth has remained almost unknown and unstudied, because it lies below great depths of water. At one place the water is six miles deep, and here the bottom lies below us deeper in the sea than Mount Everest rises above us into the sky. Though much of what is now dry land was once below the surface of the ocean, it appears that the water covering it was never very deep. Though the visible sediments themselves may be many thousands of feet thick they were deposited on the sinking floors of shallow seas. Apparently, much of the bottom of the ocean has always been ocean bottom, and during all the millions of years that the ocean has existed, the floors of the deeps as well as the shallows have been accumulating sediments dropped upon them through the waters above. These sediments, lying layer upon layer in the bottom, have become the repository of the historical record of the ocean. This record includes the contributions of the rivers, reflecting the changing conditions on the continents, as well as those of ice and wind and the myriad life in the water above. The record of what happened in this water above is filed away in the mud and clay and ooze below. The rocks and pebbles and sand brought by ice, the clay and mud brought by rivers and ocean currents, the skeletons of marine organisms which lived and died and evolved into various forms throughout the ages constitute this record. Some types of these organisms live only in cold water, others in warm water, some live in shallow lagoons, others in the depths of the open sea. Some prefer fresh water, while others survive only in salty water. Some

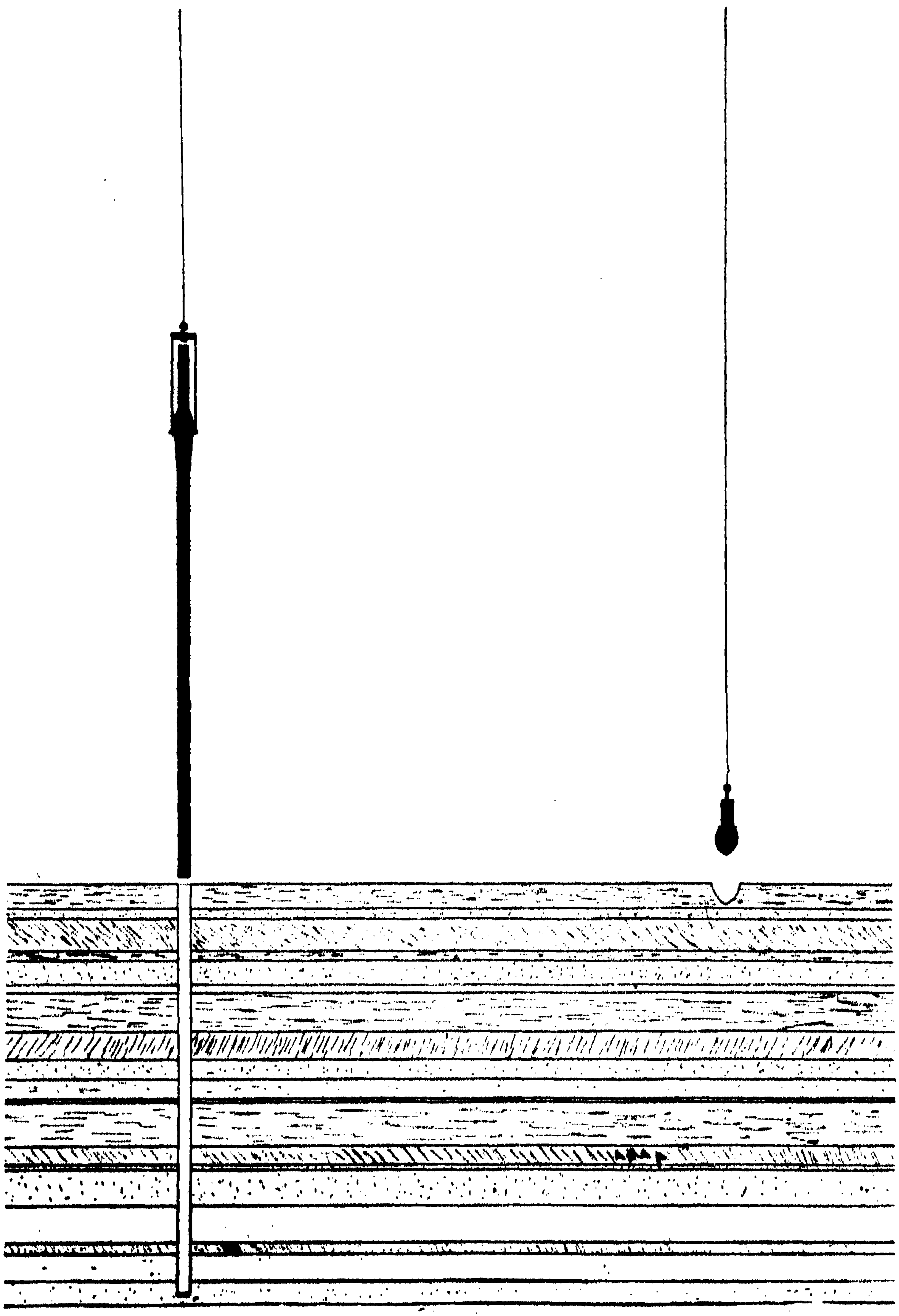

FIG. 1. COMPARISON OF SNAPPER WITH CORE SAMPLER.

lived a long time ago, and others have evolved into their present forms comparatively recently. In addition to these records of life and its many changes there exists a chemical and a physical record. Oxidation and reduction and the nature of the dissolved matter in the water have all left the record of their changes in the bottom, and the nature and size of the minerals and rock fragments bear evidence of the direction and strength of former ocean currents, the movements of ice and the depths of the ocean in the past.

Heretofore, the samples obtained from the deep ocean bottom have been a mere handful of material taken from the very surface of the bottom. These samples give information of present conditions only and reveal nothing of past events,

so that although the historical record has been known to exist we have been able to see only the topmost page.

On land the geologist studies the exposed rock strata, but a study of material lying beneath miles of water is enormously more difficult. If, however, we could bring up a vertical section of several feet of this bottom, in its original, undisturbed condition, we might read the history of oceanic events as the geologist deciphers the record in the rocks.

The need for such samples has been apparent for many years, and many attempts to secure them have been tried, but although the bottom of the ocean has long been an object of interest, its remoteness and inaccessibility have kept it literally a terra incognita.

HISTORICAL

Let us consider briefly the historical development of oceanic investigation. The traditional method of ascertaining

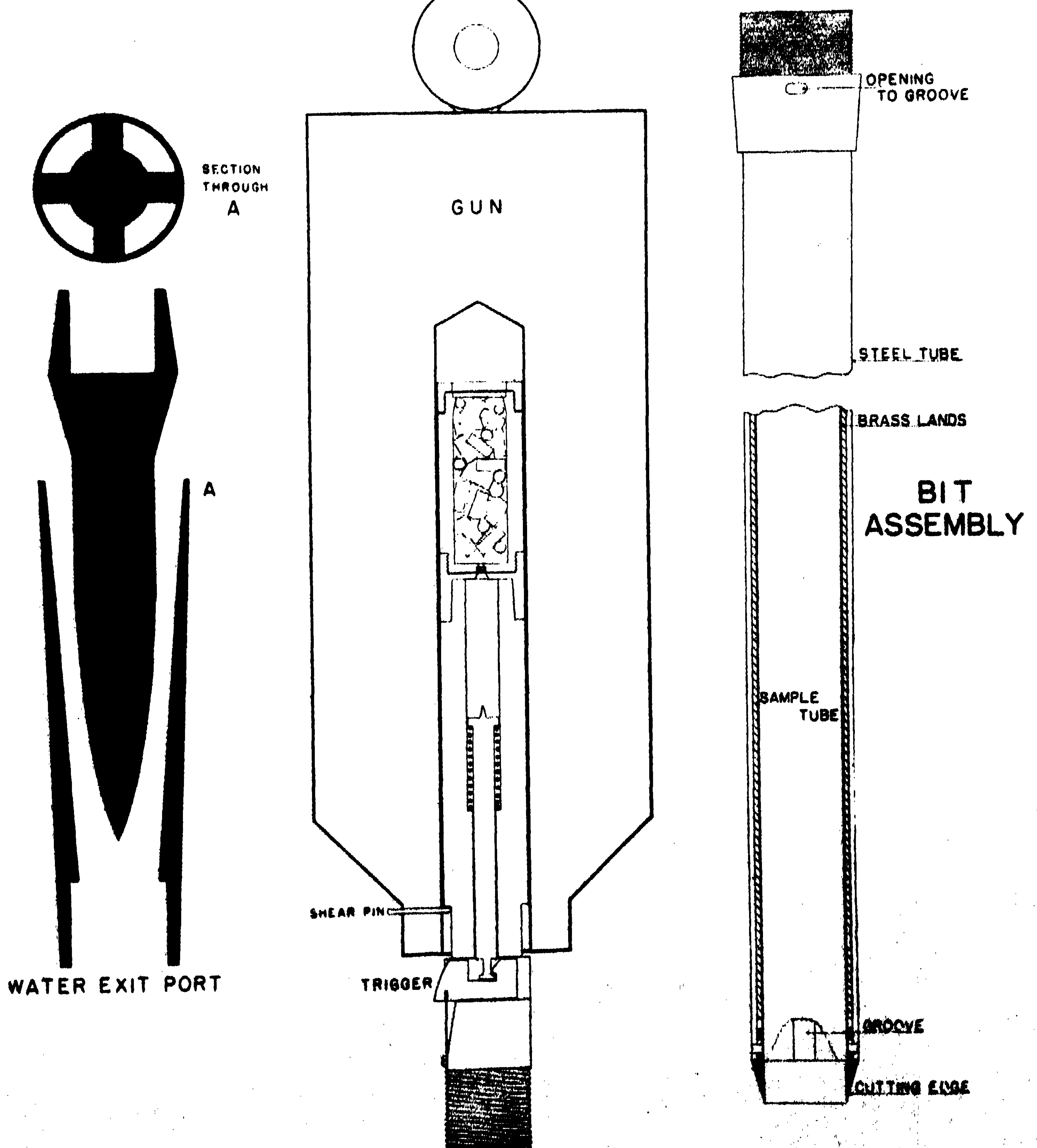

FIG. 2. DIAGRAM SHOWING THE FIVE PRINCIPAL PARTS OF THE APPARATUS, DRAWN TO SAME SCALE.

the depth of water by the simple means of lowering a weight to the bottom has been practised since the beginning of man's adventurings afloat, and quite early there was devised means of knowing something about the *kind* of bottom by the simple expedient of putting a lump of tallow on the bottom of the sounding weight, to which mud, sand or shells, characteristic of the locality, adhered. This device has been used for many hundreds of years and is to-day the chief reliance of the North Sea fishermen.

Attempts at sounding without a line were tried a long time ago, for as far back as 1450 a bathometer was invented which consisted of a floating sphere pulled down by a heavy weight which was disengaged on reaching the bottom. The time elapsing between launching and the reappearance of the sphere at the surface was a measure of the depth. Perhaps the first attempt at scientific deep ocean sounding was that made by Magellan in 1585, during the first circumnavigation of the globe, when he tried to determine the depth of the Pacific Ocean near the island of St. Paul and, because he failed to reach bottom with all his combined lines, concluded that this was the deepest part of the ocean. During his voyage to Baffin's Bay in 1817 Sir John Ross designed a "deep sea clamm" with which he brought up several pounds of greenish mud from depths as great as 1,050 fathoms, which is 6,300 feet, and the presence of worms and starfish established the fact that life existed at great depths.

In 1844 the director of the U. S. Coast and Geodetic Survey instructed its officers to preserve any bottom material brought up by the sounding machine, and this agency has made valuable contributions to the science of oceanography ever since.

By 1850 the need for a better sounding device was urgent, the heavy sounding lines necessary to bring a weight back to the surface were bulky and unwieldy, the deeper the water the stronger the line required, which, with the hemp ropes then used meant more buoyancy, therefore a heavier weight; and the heavy lines gave no indication when the bottom had been reached. As this was the essential part of the undertaking, these incompatible conditions bade fair to defeat the main objective. The difficulty was solved by Midshipman Brooke, of the Hydrographic Office of the U. S. Navy, who passed a short pipe through a hole in a cannon-ball and hung the latter from the former by a sling. This became disengaged when the weight reached the bottom, and only the small pipe with its sample of sediment was brought to the surface. This device permitted the use of a line or wire light enough to show a change in tension when the bottom was reached and yet sufficiently strong to bring up a sample. This scheme of merely pulling down a very light line by means of a weight, which is left on the bottom, is that used to-day in practically all deep-water wire soundings.

Midshipman Brooke's device greatly stimulated deep soundings, and records accumulated rapidly, so that by 1850 Lieutenant Matthew Fontaine Maury, who probably contributed more useful information about the sea than any other investigator, was able to publish the first bathymetric map of the North Atlantic Ocean. The bottom samples secured by these soundings were examined and described by J. W. Bailey, whose publications through the Smithsonian Institution constitute the first scientific information on this subject. In 1851 the U. S. S. *Dolphin* began systematic soundings in the North Atlantic, and in 1852 the U. S. S. *Arctic* ran a line of soundings from Newfoundland to Ireland in an effort to verify the existence of a submarine ridge, on which it was pro-

posed to lay a transatlantic cable. Such a convenient submarine feature does not exist, but the legend of the "telegraph ridge" still persists.

By 1870 more than 9,000 bottom samples had been taken by the U. S. Coast and Geodetic Survey, so that Dr. Louis Agassiz was able to compare dredged forms with fossil types and arrive at the fundamentally important conclusion that since the earliest times the continental areas and the oceanic areas have occupied much the same positions that they do to-day.

All this paved the way for the exhaustive investigations of the physical, chemical and biological conditions of the ocean basins carried out on board H. M. S. *Challenger* from December, 1872, to May, 1876. This expedition circumnavigated the globe, traversed the oceans in many directions, made observations in nearly all the departments of the physical and biological sciences, and laid the foundation for the science of oceanography as it exists to-day. So wide was the field and so extensive the collection assembled that a "Challenger Office" in London is even now occupied with the administration of the varied material. Although the Challenger Expedition is unquestionably the foundation of modern ocean study, it concerned itself more with the water than with the bottom of the ocean, and made no attempt to secure material from below the immediate surface of the latter. This great expedition established the fundamental datum of what *is* happening in the ocean; there is now urgent need of a similarly broad study of what *did* happen in the ocean in the past. This information is in the bottom sediments, and it is to these that we must apply our efforts.

Geological Significance

Now let us turn for a moment to a consideration of some aspects of the structure of the surface of the earth as a whole.

Those of you who heard Dr. Leason Adams speak here last October on the nature and composition of the earth's interior will recall that he used a diagram to illustrate the make-up of the earth's internal structure, whose essential meaning was that the earth has a central core of iron, a thick intermediate layer of heavy, very basic rock and a thin outer cover of less basic material called basalt. On the surface of this basaltic cover are supported here and there irregular patches of lighter rock, mostly granite, but also containing all the other rocks, sedimentary or otherwise, produced in one way or another from the original igneous material. These patches we call the continents. They cover but little more than one fourth of the total surface, while the remaining 72 per cent. is covered by water—which we call the ocean. It is apparent, therefore, that the ocean basins constitute the most conspicuous feature of the earth's surface, and no adequate study of the geologic history of this surface can afford to neglect these great areas.

The floor of the ocean is thought to be the upper surface of the great basaltic cover of the earth, and except where it has been pushed up to form volcanic islands it is, in all probability, essentially as it was when the earth became cool enough to permit water to condense upon its surface. The granitic continental areas on the other hand have undergone many changes; they have risen above the general level, been eroded down, sunk below sea-level at certain places and been heaved up again. Besides these vertical movements there have been horizontal ones—squeezings and stretchings to produce folded mountains and rift-valleys. Joly's doctrine assumes that the ocean floor as well as the continents is periodically heaved up, into a great low arch, that any cracks thereby produced are

filled by upwelling molten material from below and that subsequent sinking of this hardened arch exerts enormous crushing forces at the margins of the continents. The Wegener hypothesis assumes that there was once only one great continent, and that it subsequently broke up into several pieces, which drifted apart under the influence of tangential forces.

Brief mention is made of these geologic conceptions only to emphasize the fact that from the earliest times the interrelations existing between the ocean basins and the continental highlands have been of fundamental importance to the history of the surface of the earth.

Geologists divide this history into different periods, or ages, according to the evidence furnished by uplifted marine sediments, as for instance the Carboniferous, when a moist, warm climate filled vast swamps with rank tropical vegetation; or the more recent Pleistocene, when a cold environment caused great masses of ice to spread over large areas. Each such period deposited its characteristic page in the accumulating record at the ocean bottom. Through these ages the ocean has been receiving the material eroded from the continents, the chemical substances dissolved by the rains and the dust and volcanic ash borne by the wind. As these things changed in character or amount they left their record in the ocean's bottom. The sharp pebbles and coarse sand brought by the ice contrast markedly with the fine flocculent burden of unhurried rivers. This record has been accumulating during many changes on the neighboring continents and during many changes in the water above.

All these records have been laid down in historical sequence, and in some places this sequence has remained undisturbed throughout many geologic ages. Far out from land in the undisturbed depths of the open ocean this record has accumulated very slowly, so that a few feet of depth represent a very long interval of time.

Problems

As illustrative of the sort of investigations which a study of these sediments might be able to assist, let us consider a few typical problems. Certain chemical elements which must have been transported from the rocks of the continents to the waters of the ocean and thence to the sediments in its bottom are of great interest and significance. Some of these occur in large amounts, as, for instance, calcium or chlorine, while others of minute concentrations are none the less significant, as, for example, fluorine or selenium, manganese or radium.

The cycle followed by calcium is quite obvious. This element came originally from igneous rocks, went into the sea, where the myriad organisms built skeletons and shells of it. The organisms died and their shells settled to the bottom, where they were eventually covered and compressed and heated to form chalk, limestone or marble, which was later pushed up into hills to be eroded away and again returned to the ocean.

The story of fluorine is not so clear. This substance is almost as abundant in the original igneous rocks as its chemical companion chlorine. Now chlorine, as sodium chloride, is a dominant constituent of sea-water, but this is not true of fluorine, nor has this element yet been found in appropriate amount in the bottom sediment. It is found in phosphate rock deposits, but although these are large they are hardly sufficient to balance the cycle.

Ores of manganese are relatively rare on land, but quantities of manganese nodules occur on the ocean bottom and in some places there appear to be vast slabs of it covering many square miles. Why this is so we do not know, but in working out the answer we shall probably learn of other facts as yet unsuspected.

The case of the accumulation of radium in the ocean sediments is most in-

triguing, and it was our work with this element that led us into the ocean bottom.

During the last cruise of the non-magnetic ship *Carnegie* a number of samples of bottom were secured from deep water by means of the "telegraph snapper," an instrument used by the submarine cable engineers to give some knowledge of the character of the surface of the bottom. These samples were examined for a great many things, including radium, and, as shown in Table 1, it was found that they possessed a concentration of this element far greater than that existing in the igneous rocks from which it must have come. It will be noticed that the radium concentration is given in grams times ten to the minus twelve per gram. Expressed as a vulgar fraction this is one, over one followed by twelve zeros. This is an exceedingly small amount of radium, but this element possesses to a high degree that phenomenon known as radioactivity whereby the nucleus of the atom periodically explodes and expels from within itself some of its own substance. This explosive activity produces electrical effects by means of which the very small quantities shown may be determined. It also produces a great deal of heat, so much in fact that one gram of radium element, in equilibrium with its disintegration products, continuously gives off 140 gram calories of heat per hour, which is enough to melt more than its weight of ice in that time. It is quite probable, therefore, that radioactivity is a very important factor in geophysical phenomena, and of the several elements that exhibit this activity the most important are radium, thorium and potassium, the first two because of the intensity of their activity, and the last because of its great amount in the rocks. It is the radioactive heat that Joly postulated was able to melt the lower portion of the basaltic layer and, by expanding, to push up the low arch mentioned before. Whether or not it can do such a spectacular thing, it is evident that here is a source of enormous energy which must be seriously considered. Though there is but little radium in each gram of rock there are many grams of rock, and this rock is not a good conductor of heat—and furthermore, geologic time is long—so that it is quite possible that this heat might accumulate sufficiently to account for some of the geophysical phenomena that have been observed.

TABLE 1

COMPARISON OF RADIUM CONTENT OF ROCKS AND OCEAN-BOTTOM SEDIMENTS

		grams × 10^{-12} per gram of sample
Granites		2.0–5.0
Basalts		0.8–1.3
Sedimentary (various ages)		0.1–1.2
Ocean Bottom		
Average of 12 (Joly)		17.8
" " 28 (Petterson)		10.96
Carnegie Samples		
Type	Depth in meters	
Terrigenous	2604	1.80
"	2911	1.88
"	5396	4.12
"	5545	4.76
"	5198	3.00
Blue Mud	4026	3.08
Globigerina Ooze	4693	3.96
" "	2614	3.88
" "	3393	3.40
" "	3610	4.40
" "	3080	3.64
" "	2898	5.00
" "	3423	5.96
" "	3353	7.84
Red Clay	4007	3.20
" "	3879	3.96
" "	4418	5.80
" "	3806	9.60
" "	5320	6.04
" "	4426	8.96
" "	4713	9.48
" "	5208	10.40
" "	4918	21.40
" "	5003	16.72
" "	4953	10.92
27 Red Clays average		12.1
13 Globigerina Oozes average		4.1

Table 1 shows that the concentration of radium in the uppermost sediments of the ocean bottom is much greater than in either the igneous or sedimentary rocks on land. This high radioactivity is the more astonishing when it is remembered that the sedimentary materials of the continents, even the shales and limestones which were formed under the sea,

contain in general less radium than do the igneous rocks. The geophysical significance of this highly radioactive material depends upon the thickness of the sediments and their history subsequent to being formed. If they are of shallow depth and have not entered into the basaltic crust, their radium content is of little geophysical significance, but if they are of great thickness and have served to take such concentrations of radium into this crust, their influence must be considerable, either as blanketing the flow of heat into the oceans, as is required for Joly's thermal cycles, or as providing sources of intense energy for any part of the crust within which they may become incorporated. The concentration appears to be greatest in those portions of the ocean bottom more remote from land and lying at the greater depths, where the material generally consists of so-called red clay, and it is this material that appears to contain much more radium than any rocks yet examined on land. If these sediments are of considerable thickness, and if this radium concentration is the same throughout, these deeps constitute local concentrations of radioactive material possessing enormous stores of energy. Since we have found no sedimentary rocks with radium concentrations remotely approaching those existing in these deep sediments, it might be inferred that the deeper portions of the ocean, unlike the high mountains, are permanent features of the earth, vast depressions which, since the very beginning of the ocean, have been receiving, together with other things, a large accumulation of radium. Or, on the other hand, this radium concentration may be but a transitory thing, for if this be elemental radium which has separated from the sea-water entirely on its own and is not in equilibrium with its parent substance uranium, it will disappear, almost entirely, in 10 or 20 thousand years, which is only a moment in geologic time. This is because the half life of radium is only 1,600 years, which means that a given amount of radium to-day will diminish to one half this amount in 1,600 years, and this again to one half in another like period, and so on. Consequently, if this radium is "on its own" in the bottom sediment, it must disappear almost entirely below some 20,000 years of accumulation. It has, however, been found one meter below the surface and there is reason to assume that it is not alone, but is being continuously produced by its parent uranium, and that it is due to the chemical behavior of this parent element that a separation from sea-water takes place.

Various mechanisms have been suggested to account for this high concentration of radium in the ocean bottom, some of which seem to have lost sight of the fact that in all probability the significant chemistry involved is the chemistry of uranium and not that of radium per se.

It has been suggested that the concentration is brought about by the numerous minute living organisms in the sea. These are assumed to extract, more or less selectively, the salts of uranium and radium from the sea-water, and to incorporate them in their skeletons, and when they die their remains take the radioactive material to the bottom. If the concentration is brought about by sea organisms we should expect to find some connection between the radium content and the character of animal remains comprising the sediment. Although a few high figures are associated with globigerina or radiolaria deposits, the red clays, which are predominantly mineral in composition, show more consistently higher radium contents. If we confine our averages to the more recent analyses we arrive at the figures (see Table 1):

27 red clays average 12.1×10^{-12} grams Ra per gram.
13 globigerina oozes average 4.1×10^{-12} grams Ra per gram.

The uranium must have come originally from the igneous rocks. It exists in the water in solution, and apparently some process is operating to remove it from this solution and to cause it to accumulate in the bottom-sediments at a concentration considerably greater than in the igneous rocks.

The fact that the radium concentration falls off near shore and there approaches more or less the concentration found in sedimentary rocks, which accumulated in shallow seas, indicates that the process is not one of detrital accumulation or sedimentation. Furthermore, the fact that the higher concentration is found in the red clays, which are assumed to accumulate very slowly, and the minerals of which may be partly formed in place, indicates that the skeletal remains of organisms tend to dilute an otherwise higher concentration.

Chemically, uranium, iron and manganese are similar, in so far as their oxides are among their less soluble compounds, and it is usually in those portions of the ocean bottom where the oxides of manganese and iron are separated, as revealed by the nodules of these elements, that the uranium concentration—as revealed by the radium content—is the higher.

If we accept the radium content of sea-water as being about 0.02×10^{-12} grams per cc (which is probably high), which corresponds to a uranium concentration of 6×10^{-8} grams per cc, we find that the uranium is not very greatly different from other metallic constituents such as silver, gold or even silicon, from which so many marine organisms build their skeletons (Table 2). In all probability there are several factors aiding in its separation and concentration in those places where it is found to be most abundant. Skeletal remains may take down some, also dust particles of volcanic or other origin may adsorb some and sweep it to the bottom; but probably the greater proportion comes out as the result of oxidation. Water which is near enough to continents, or shallow enough to have sufficient organic material at the bottom to maintain a slightly reducing environment, tends to keep its uranium in solution, whereas the very deep bottom waters, far from land, do not contain organic material either washed from the land or as undestroyed organisms; consequently they afford an oxidizing environment. That these waters are oxidizing is borne out by the direct measurements of the oxygen content with depth made by the *Carnegie,* a typical graph of which is shown in Fig. 3. This shows that the environment at the bottom of the ocean is of an oxidizing rather than reducing nature. In the deeper parts of the ocean where there is little movement, the water at the bottom must be at saturation with respect to the oxides of uranium. There is, therefore, a tendency for them to separate out just as the iron and manganese do.

TABLE 2

URANIUM AND SOME OTHER METALLIC CONSTITUENTS OF SEA-WATER

Uranium	6.0×10^{-8}	grams per cc
Silicon	46.9×10^{-8}	" " "
Silver	10.0×10^{-8}	" " "
Gold	0.06×10^{-8}	" " "

APPARATUS

Nearly all the ocean-bottom samples hitherto obtained have consisted of a small amount of material taken from the immediate surface. They yielded no knowledge of what lay below—no perspective of sequence or time. To cope with the types of problems just discussed it is necessary that an undisturbed cross-section of the bottom sediments be obtained, the deeper the penetration the better, but it is essential that the sample reach the laboratory in exactly the condition existing in the bottom of the ocean.

These requirements have been met by an apparatus which has been developed by virtue of the generous cooperation of

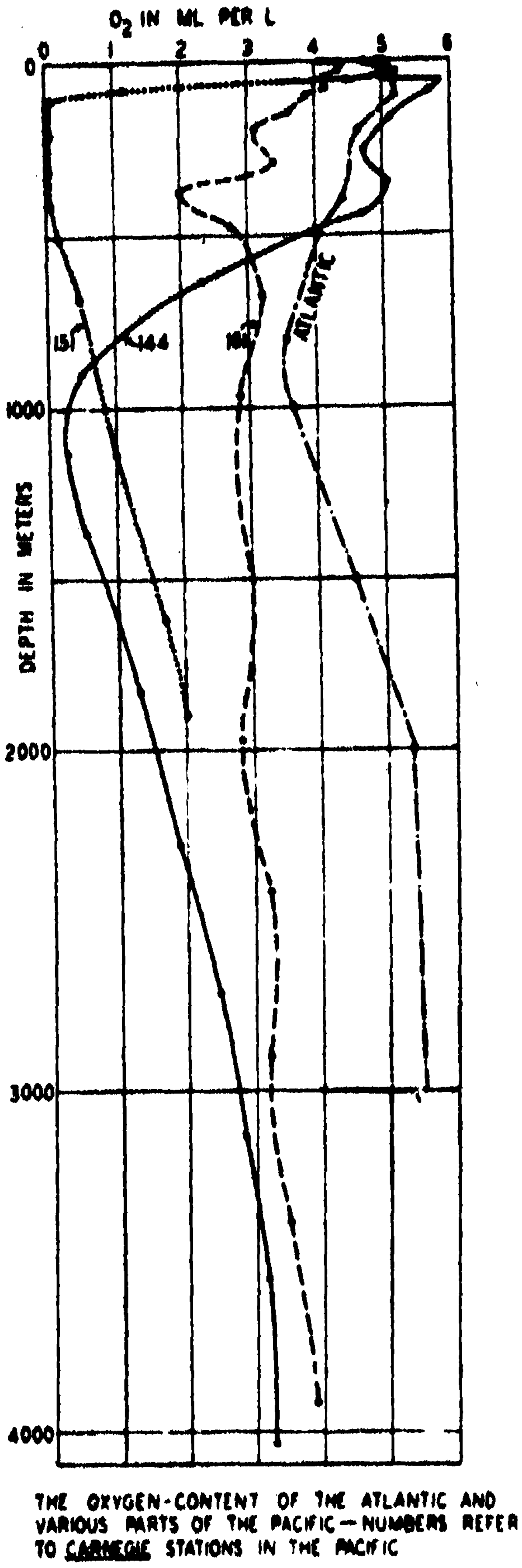

FIG. 3. OXYGEN CONCENTRATION IN THE SEA AT VARIOUS DEPTHS.

many persons, particularly that of Dr. B. F. Mackey, ballistics expert of the E. I. du Pont Powder Company, and the U. S. Lighthouse Service, from whose tenders many tests were conducted. This apparatus has obtained undistorted cores as much as ten feet long, from bottoms lying more than three miles below the surface of the water, and we believe it will function satisfactorily even at the bottom of the greatest deep, which is 5,900 fathoms, or more than six and one-half miles down. There the hydrostatic pressure is 16,000 pounds per square inch.

Now the requirements for an apparatus designed to operate at the end of a line under several miles of water, and at great hydrostatic pressures, are varied and somewhat conflicting. One can not lower a weight faster than the winch can run the line out, and furthermore, skin friction is such that a considerable weight sinks slowly with several miles of line behind it and arrives at the bottom with almost no kinetic energy. Consequently in deep soundings one can not rely on the energy of a falling weight to do any considerable work at the bottom. Nor is it feasible to send the necessary energy down a sounding line, as, for instance, in the form of electricity. No wire rope made can support the weight of six miles of itself and retain any reasonable factor of safety, and an insulated electric conductor would diminish this strength considerably.

Even if insulation and mechanical difficulties were overcome, such a rope could not long survive the constant bending over sheaves and drum at high tension, and any motor designed to operate machinery under several miles of corrosive sea-water would be so bulky and heavy, to say nothing of cost, as to be out of consideration. A heavy weight is an asset on the way down, but a liability on the way up, and sufficient strength must be reserved to pull the sample out of the mud once it is secured. Furthermore, the pitching and rolling of the ship on the waves at the surface impose strains on the rope far greater than those of dead weight or the pull-out. The fact that no one rope is strong enough in proportion to its weight necessitates the construction of a tapered rope, which becomes bigger and stronger as the weight increases. Such a rope greatly complicates the spooling, or winding on the winch drum, for unless this is done smoothly and compactly, the enormous pressures of superimposed layers under tension will cause cross-lapped ropes to crush and cut each other.

Any satisfactory apparatus should be

as light as possible, of simple design and operation and of rugged construction. It should be capable of attachment to any existing sounding line strong enough to hold it, and it must function entirely automatically on reaching the bottom. For this reason, it must possess within itself the energy necessary to accomplish the work to be done.

Of all the sources of energy considered, that possessed by modern military powder seemed most likely to succeed. It is highly concentrated, presents no special problems of manipulation, and may be varied in intensity and amount to suit the changes of hydrostatic pressure or the resistance of the bottom material.

The apparatus, in its present state of development, consists of five parts: a weight, or gun, a cartridge, a firing mechanism, a water exit port and a bit. These parts are shown in Fig. 2 drawn to the same scale. The gun is made of ordinary cold rolled steel 10 inches in diameter and 22 inches long. The cartridges, trigger and housing are of stainless steel. The water port is of welded steel, and the bit of a special alloy steel developed for airplane construction. Only the cartridges must withstand the great hydrostatic pressures, and since they are designed for high internal pressures, this presents no particular difficulty. They consist of three parts—a midsection or powder chamber and top and bottom sections. In the bottom of the powder chamber is a recess into which a rifle primer fits. Over this is placed a thin steel disk, against which the bottom section screws tightly, in the center of which is a small hole, opposite the primer, through which the point of the firing-pin may strike the disk with sufficient force to distort it and thereby fire the primer.

Inside the muzzle end of the powder chamber rests a hardened steel disk, one-eighth inch thick, with its outer surface flush with the end of the powder chamber. Its function is to take the strain of the hydrostatic pressure of the sea-water and thereby prevent distortion of the rupture disk. The rupture disk is of steel and of such thickness and strength that it will allow the pressure within the cartridge to build up to the proper working pressure before it ruptures and releases the energy to the mechanism.

Powder Charge

The explosive charge which furnishes the energy necessary to do the required work varies with the depth and the character of the bottom. The charge consists of a primer, 1 gram of high-speed black powder, 1 gram of rifle powder and a varying number of pellets of 155-mm howitzer powder. The 2 grams of small powder play the double role of promoting ignition and quickly building up a pressure, in which environment the large-grained powder functions explosively. If this high pressure were not provided, the latter would not burn properly.

The total available energy is regulated by counting into the cartridge a varying number of pellets of the big powder. This required energy is of three parts: (1) That which is necessary to overcome the hydrostatic pressure at a particular depth; (2) that which is necessary to overcome the inertia of the bit and to put it in motion; and (3) that required to drive the bit into the particular material encountered. Only the second can be determined in advance; the other two must be provided for at each sounding. The possible work that can be done is a combination of the total available energy and an intensity factor, *i.e.*, the pressure at which the explosive gases are released. This "working pressure" is controlled by the steel rupture disk at the mouth of the cartridge. Up to the time this disk is blown out, the powder is protected from the water. These disks are relatively thin and, therefore, capable of distortion, and at a certain depth the hydrostatic pressure might conceivably be greater

than the desired "working pressure"—hence the use of the steel "hydrostatic pressure disk," which relieves the rupture disk of all strain. By virtue of this arrangement, and the use of the large-grained powder, there is obtained a more or less automatic adjustment of the delivered power to the required work. For example, if 30 pellets of big powder are put into a cartridge and it is sent to 1,000 fathoms and encounters a stiff clay, the added pressure and resistance will cause the powder to burn more rapidly, and all of it will be converted into gas; whereas, if the same charge encountered a very soft bottom at a shallow depth, only that powder would be consumed which had burned up to the time the muzzle was cleared—which would occur sooner than in the former case. The optimum load, therefore, is one which leaves a grain or two of partly burned powder in the cartridge. The ultimate condition is that which exists when the bit lands on solid rock and all the energy must go into moving the gun, which is then blown upward and thereby saves the apparatus from destruction. The bits have been made strong enough to meet this extreme condition.

The firing mechanism consists of only three parts, a trigger, firing-pin and spring. A safety-pin of hardened steel is put in place before the cartridge is attached, and this is withdrawn by means of a lanyard just before the apparatus goes under the water. Should it be necessary to return the apparatus to the deck, before firing, this pin can be inserted again before the apparatus is hoisted over the side.

Because of the high velocity of the bit at the time of firing, the water within it acts as a solid body. During early experiments the bit was often driven deep into the mud, but no samples were obtained. The water exit port gives the bit an open-tube condition at the top while keeping the force of the explosion centered along the axis of the bit. The length of the bit determines the possible length of the sample. Bits of different lengths may be used as found desirable. Those now being used are 10 feet long. Inside the steel tube are four grooves cut longitudinally from top to bottom. Their function is to provide channels by which water may get down to the bottom of the bit and to fill the cavity in the mud created by the withdrawal of the bit and its

FIG. 4. APPARATUS READY TO SOUND, SAFETY-PIN BEING PULLED BY LANYARD.

sample. A thin-walled brass sample-tube fits inside the steel bit, and it is this tube that receives the sample. The bottom of the bit is fitted with a hardened cutting edge which fits loosely, in such a manner as to act as a valve to prevent mud from entering the water grooves while the bit is being driven into the bottom, but which opens and permits water to flow out of the grooves while the bit is being withdrawn from the mud.

FIG. 5. BIT RETURNED TO SURFACE, HANGING FROM STIRRUP. GUN IS ABOVE, OUT OF THE PICTURE.

After a "shot," the brass sample tube is withdrawn, with the mud core inside it, and a new one is inserted. It is cut off at the top of the mud, corked at both ends, and these corks securely taped. They are labeled in a manner to indicate the top and the bottom of the core and may then be shipped and kept without alteration until opened for examination in the laboratory. This is done by cutting the tube longitudinally in two diametrically opposite places and then inserting two sheets of tin in one slot and pressing them across to the opposite wall. The tube may then be opened hinge-fashion and the tin strips removed without distorting the sample. This produces two equal parts to each sample, each part lying in its own brass trough, and reveals the structure of the core. This procedure provides an undisturbed half for control or future reference and the other may be used for investigation. Furthermore, the undisturbed half provides a depth scale, from the surface downward, which is of considerable value. It has been found convenient to split the half to be examined, either in half again or into quarters. The fragments may always be returned to their proper place in the brass trough.

Sounding Procedure

The apparatus is assembled in chocks, so arranged that when it is laid in them the center of the bit and cartridge coincides with the center of the bore of the gun. The firing mechanism is cocked and the safety-pin inserted. A cartridge is loaded in accord with the anticipated need. If it is the first sounding in a new locality, it is advisable to provide rather less than the required energy. Subsequent loads may be increased as circumstances warrant. When all is ready, the cartridge is fastened in place and the gun "loaded," by sliding the bit toward the gun, and the shear pin is put in place. The apparatus is then hoisted over the

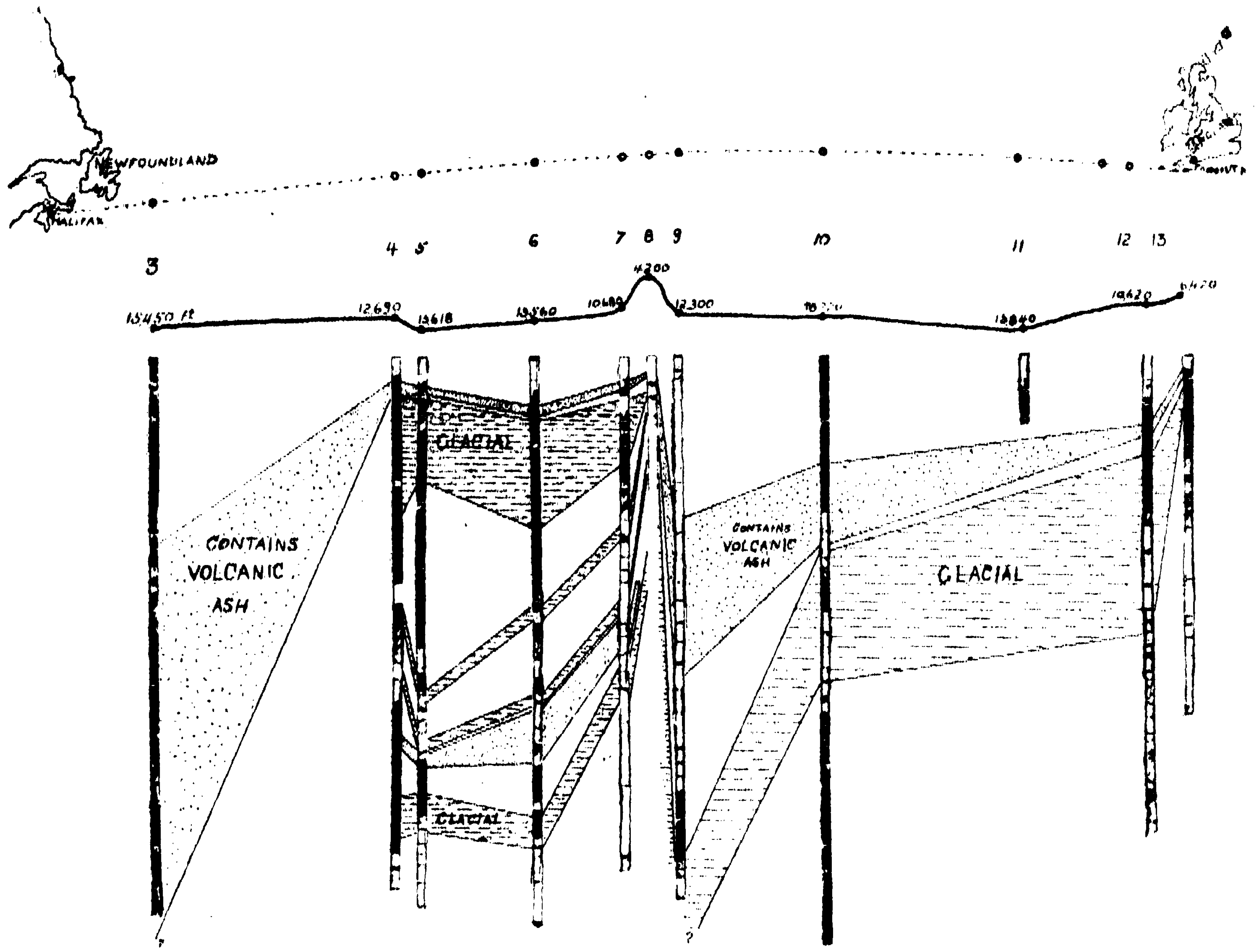

FIG. 6. NORTH ATLANTIC CORES, SHOWING DEPTH AND LOCATION OF EACH AND THE RELATION OF THE GLACIAL AND VOLCANIC-ASH STRATA.

side. A man picks up the bit at the cutting edge and, as soon as the gun clears the rail, he drops his end over the side into the water. The apparatus is immediately lowered until only the gun is out of water; this prevents swinging against the ship's side (Fig. 4). Finally, the safety-pin is pulled out and the apparatus is lowered to the bottom. With shallow soundings the explosion can be heard and felt on the ship, and with deeper ones it may also be picked up by a microphone or the ship's sonic sounder. Where these fail to give any indication, the cable is paid out until more than the anticipated depth is out, and then the apparatus is hauled to the surface again. If it has fired, the gun and bit will be hanging separately at the end of their respective cables, the bit supported in the stirrup (Fig. 5).

With the cooperation of the Woods Hole Oceanographic Institution, sixteen soundings were made at sea in August, 1935, yielding the 14 cores shown in Fig. 7. One failure was due to a defective primer, and once the core pulled out. The 14 cores vary in length from 4 feet to nearly 9 feet and are solid throughout. The depths of these soundings varied from 200 fathoms to 1,250 fathoms.

The 11 cores shown in Fig. 9 were obtained from the Western Union Cable Ship *Lord Kelvin* during May, 1936, between the Grand Banks of Newfoundland and the edge of the continental shelf southwest of Ireland.[1] Seven of them

[1] The success of this undertaking is due to the courtesy of Mr. Newman Carlton, chairman of the board of directors of the Western Union Telegraph Company, and of Vice-President F. E. d'Humy and Mr. G. H. Ridge, and especially to the enthusiastic cooperation of Lieutenant Commander Bredin Delap (R. N., retired), then in command of the ship, and acting 1st officer W. Adamson. Thanks are particularly extended to Chief Engineer Tierney and his staff, who made many emergency repairs. From every

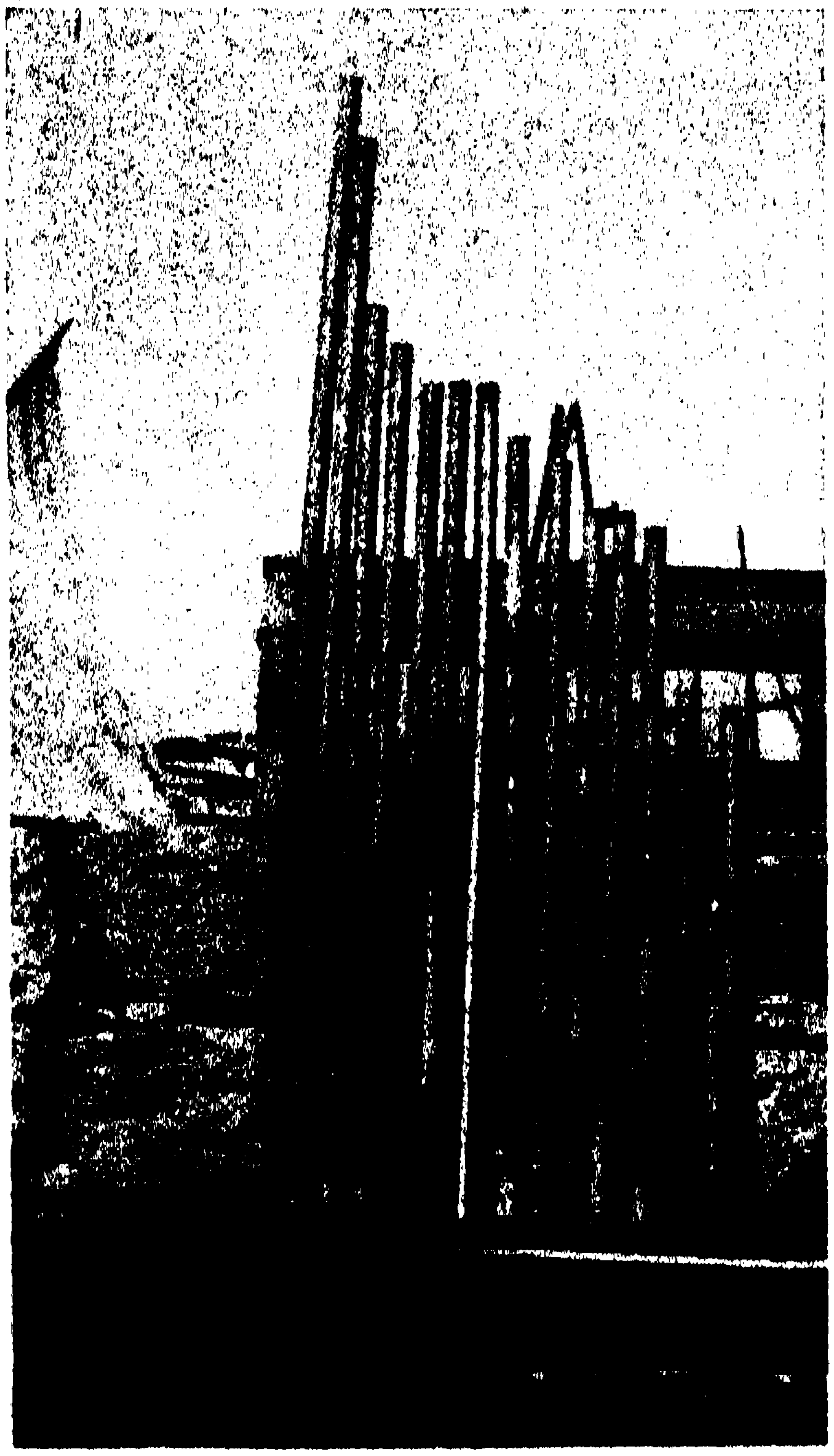

FIG. 7. CORES TAKEN FROM SUBMARINE CANYONS AUGUST 1935, AT DEPTHS OF 1,200–7,500 FEET. 6-FOOT RULE FOR COMPARISON.

are from depths greater than 2,000 fathoms, and all the remainder but one from more than 1,000 fathoms. The one exception is from the top of the Faraday Hills at 700 fathoms. The greatest depth was 2,650 fathoms. The very short core contains several inches of weathered rock.

Fig. 8 shows these cores split open ready for study, arranged, as taken, from west to east across the North Atlantic. The cracks are due to drying. This can be prevented by keeping the cores in a saturated atmosphere, but since the dried segments leave marks on the brass troughs which establish their positions from the surface, this is not usually done.

In February, 1937, again with the cooperation of the Woods Hole Oceanographic Institution, cores were obtained from the Bartlett Deep, between Jamaica and Cuba, at a depth of 2,800 fathoms or 16,800 feet (more than three miles).

The North Atlantic cores are being studied by a group of cooperating specialists associated with Dr. W. H. Bradley, of the U. S. Geological Survey. This group also includes Messrs. M. N. Bramlette, J. A. Cushman, L. G. Henbest, K. E. Lohman and P. D. Trask. The final results of their studies are not yet available, but enough has been completed to show that within the reach of the ten-foot bit are records of four glacial periods, and two periods characterized by the presence of fragments of volcanic ash. These are illustrated in Fig. 6. Core No. 3 is entirely "blue mud" or recent sediment. This is probably due to the presence of the Labrador Current, which has

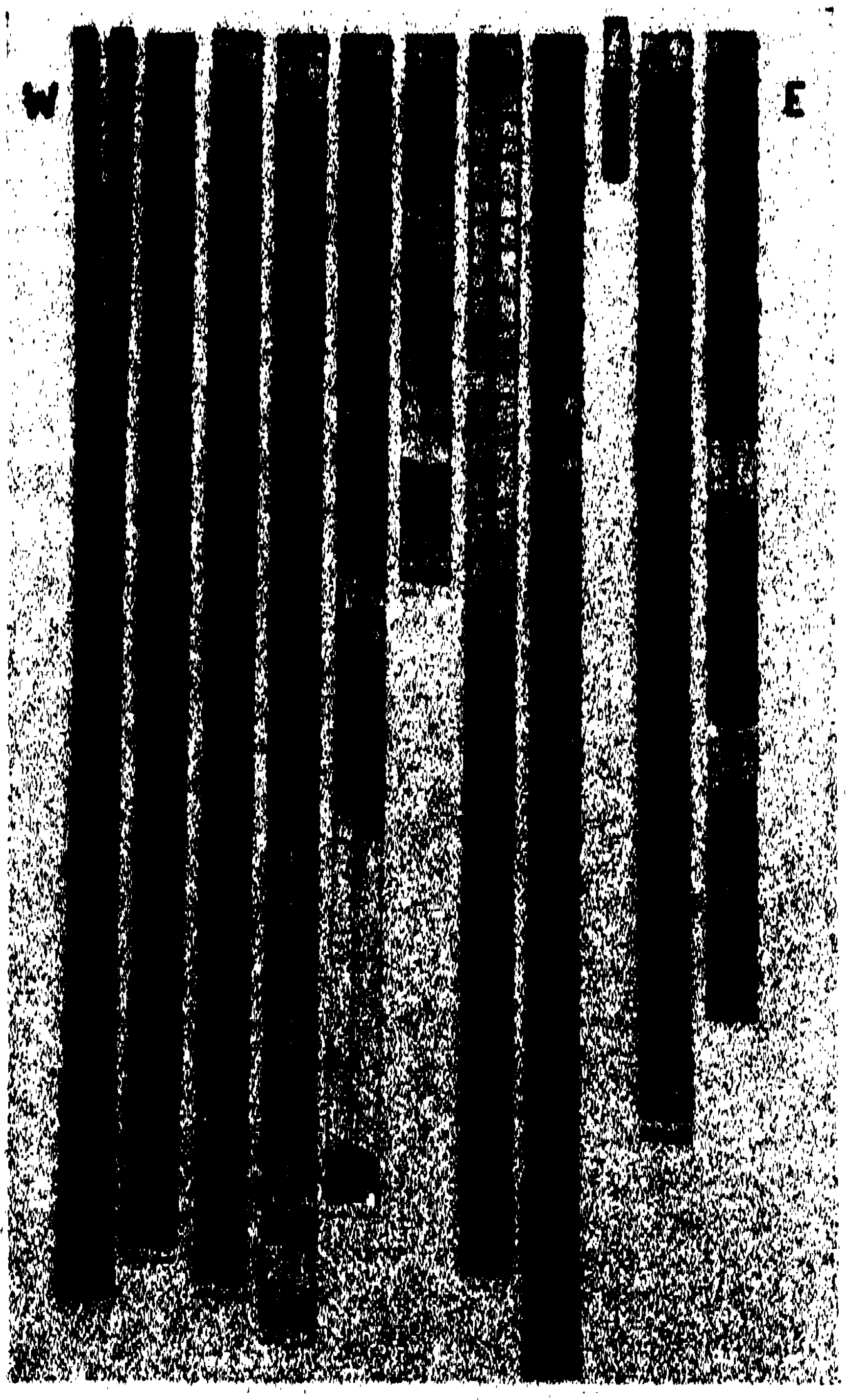

FIG. 8. SAME CORES AS FIG. 6 SPLIT LONGITUDINALLY AND ARRANGED AS TAKEN FROM WEST TO EAST.

officer and man on the ship there was always a friendly spirit of interested cooperation and courtesy which made the undertaking a delightful experience as well as a success.

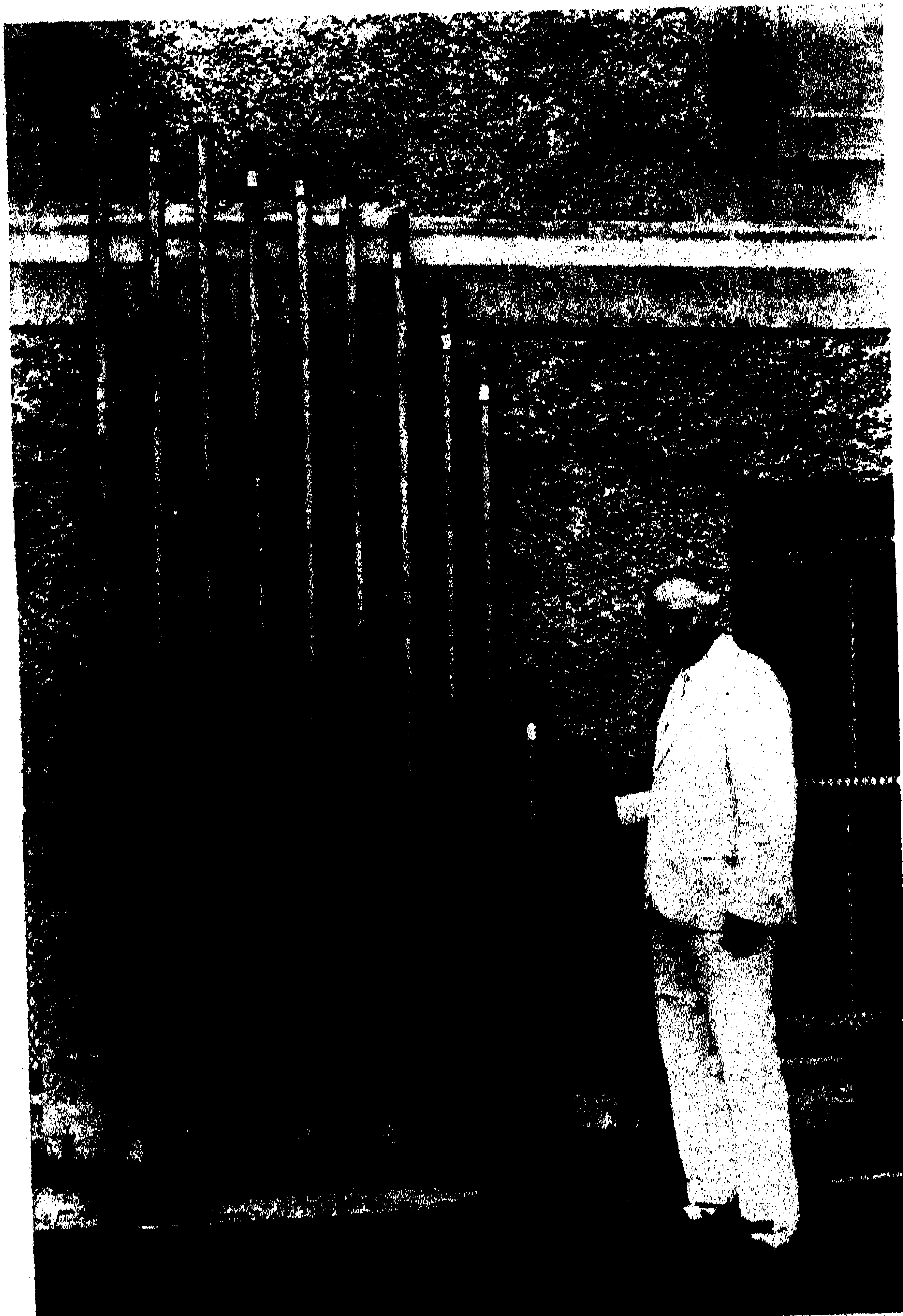

FIG. 9. CORES FROM THE NORTH ATLANTIC BETWEEN NEWFOUNDLAND AND IRELAND, 1936. DEPTHS 4200–15,900 FEET. LONGEST IS 10 FEET, SHORTEST CONTAINS SOME ROCK.

brought additional material to that region during the time represented by the upper portion of the other cores. From Core No. 4 to Core No. 8 the six characteristic strata can be traced. Core No. 8 was taken from the top of the Faraday Hills, as the Mid-Atlantic Ridge is called at that place. The general set of the water in that part of the North Atlantic is toward the east and northeast, and apparently this tends to sweep material off the top of this high, narrow ridge and deposit it in the valley beyond. Therefore the cores taken between the Ridge and the continental shelf off Ireland did not penetrate through to the three other glacial zones which undoubtedly lie buried there. The chemical, mineralogical and biological information yielded by these samples is equally definite. The biological agreement is particularly striking. Dr. Cushman made his studies of the foraminifera quite independently of the geological group. He prepared a diagram indicating cold and warm water periods as revealed by the remains of these minute creatures. When this diagram was superimposed upon the stratigrapher's map it fitted with astonishing coincidence. Between the glacial periods and below the lowest glacial zone the forms indicate that the water was as warm or warmer than it is to-day.

Dr. Byers, of the U. S. Department of Agriculture, is finding in these cores the lost selenium, which is found in the soil and in river waters but not in sea-water.

An unexpected and rather spectacular investigation is being undertaken by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, which is finding these cores helpful in a study of the changes in the orientation of the earth's magnetic field. Consider a minute particle of a magnetic mineral (and there are many such) settling slowly through the quiet water at the bottom of the ocean. Like a tiny compass needle it orients itself along the line of the magnetic force at that place and at that time. A multitude of such particles become buried in the sediment, and their orientation in these cores can be determined by delicate electrical apparatus. Therefore, as this orientation shifts back and forth throughout the length of the core, it reveals the cyclic changes of the lines of magnetic force throughout the past. Here is a record such as the non-magnetic ship *Carnegie* might have compiled had it been cruising the seas for several hundred thousand years or so.

Conclusion

The two greatest features of the earth's surface are the continental elevations and the oceanic basins. The drainage from the former into the latter has been a continuing process since the beginning of geologic history. This drainage has been the mechanism whereby this historical record has been compiled. Although the portion of this record corresponding to remote ages can not be reached, a considerable period of more recent geologic time can be studied. The first requirement is a study of a "normal" drainage—one not affected by agriculture or industry—and one which is continental in its scope. The two greatest drainage systems of the world, namely, the Amazon and the Congo, meet these requirements. They both drain large continental areas and deposit their burden in the South Atlantic. Both are practically unaffected by agriculture or industry. A physical, chemical and biological study of the sediments from well within such a river's mouth, out across the submerged delta, across the zone of increasing effect of salt water and into the deep ocean-basin beyond, would teach us much of the processes reflecting the relationships now existing between these great continental areas and the receptive sea. Knowledge of such normal, present relations would enable us to recognize abnormal conditions elsewhere (as of the Mississippi, the Ganges or the Yangtze) and to interpret the evidence contained in the record of the more distant past.

THE TRANSMUTATION OF MATTER

By the late LORD RUTHERFORD OF NELSON[1]

THE TRANSMUTATION OF MATTER

I HAVE so far spoken of the importance of science as a factor in national development, but before concluding my address, I would like to refer to some investigations in pure science in which I have been personally much interested. I refer to the successful attack on that age-old problem of the transmutation of matter which in recent years has attracted so much attention from physicists throughout the world.

I hope it may prove of interest to give a brief account of the successive stages of the growth of our knowledge of this subject, for it illustrates in a striking manner the power of the scientific method of attack on what at first appeared to be an insoluble problem. Incidentally these researches have yielded us precious information on the structure of all atoms, and indeed it seems likely to have provided us with a key, so to speak, to unlock the secrets of the constitution of our material world.

Towards the close of the nineteenth century, when it seemed certain that the atoms of the elements were unchangeable by the forces then at our command, a discovery was made which has revolutionized our conception of the nature and relations of the elements. I refer to the discovery in 1896 of the radioactivity of the two heaviest elements, uranium and thorium. It was soon made clear that this radioactivity is a sign that the atoms of these elements are undergoing spontaneous transmutation. At any moment, a small fraction of the atoms concerned become unstable and break up with explosive violence, hurling out either a charged atom of helium, known as an α particle, or a swift electron of light mass, called a β particle. As a result of these explosions, a new radioactive element is formed and the process of transmutation once started continues through a number of stages. Each of the radioactive elements, formed in this way, breaks up according to a simple universal law, but at very different rates. In a surprisingly short time, these successive transformations were disentangled and more than 30 new types of elements brought to light while the simple chemical relations between them were soon made clear.

We had thus been given a vision of a new and startling sub-atomic world where atoms break up spontaneously with an enormous release of energy quite uninfluenced by the most powerful agencies at our disposal. Apart from uranium and thorium and the elements derived from them, only a few other elements showed even a feeble trace of radioactivity. The great majority of our ordinary elements appeared to be permanently stable under ordinary conditions on our earth. Science was then faced with the problem whether artificial methods could be found to transmute the atoms of the ordinary elements. Before this problem could be attacked with any hope of success, it was necessary to know more of the actual constitution of atoms. This information was provided by the rise of the nuclear theory of atomic structure which I first suggested in 1911. The essential controlling feature of all atoms was found to reside in a very minute central

[1] Concluding part of the presidential address before the Indian Science Congress Association, prepared by Lord Rutherford before his death and presented to the congress meeting in Calcutta on January 3. This is the last part of the address, which contains two other sections—one on "Science and Industry in India" and one on "Industrial Research in Great Britain."

nucleus which carried a positive charge and contained most of the mass of the atom. A relation of unexpected simplicity was found to connect the atoms of all the elements. The ordinary properties of an atom are defined by a whole number which represents the number of units of resultant positive charge carried by the nucleus. This varies from 1 for hydrogen to 92 for the heaviest element uranium, and with few exceptions all the intervening numbers correspond to known elements.

On this view of atomic structure, it was evident that, to bring about the transmutation of an atom, it was necessary in some way to alter the charge or mass of the nucleus or both together. Since the nucleus of an atom must be held together by very powerful forces of some kind, this could only be effected by bringing a concentrated source of energy of some kind to bear on the individual nucleus. The most energetic projectile available at that time was the swift α particle spontaneously ejected from radioactive substances. If a large number of α particles were fired at random at a sheet of matter, it was to be expected that one of them must occasionally approach very closely to the nucleus of any light atom in its path. In such a close encounter, the nucleus must be violently disturbed and possibly under favorable conditions the α particle might actually enter the nuclear structure.

This mode of attack upon the nucleus at once proved successful. I found in 1919 that nitrogen could be transformed by bombardment with fast α particles. The process of transmutation is now clear. Occasionally an α particle actually enters the nitrogen nucleus and forms with it a new unstable nucleus which instantly breaks up with the emission of a fast proton (hydrogen nucleus) and the formation of a stable isotope of oxygen of mass 17. About a dozen of the light elements were found to be transformed in a similar way. The protons liberated in the nuclear explosions were at first counted by observing the flashes of light (scintillations) produced in phosphorescent zinc sulfide. This method was slow and very trying to the eyes of the observers. Progress, however, became more rapid and definite when electrical methods of counting individual fast particles were developed. These electrical counters, mainly depending on the use of electron-tubes for magnifying small currents, have now reached such a stage of perfection that we are able to count automatically individual fast particles like α particles and protons, even though they enter the detecting chamber at a rate as fast as ten thousand per minute. By other special devices, we are in like manner able to count individual β particles. In this connection, I must not omit to mention that wonderful instrument, the Wilson expansion chamber, which makes visible to us the actual tracks of flying fragments of atoms resulting from an atomic explosion. These remarkable devices have played an indispensable part in the rapid growth of knowledge during the last few years. It is to be emphasized that progress in scientific discovery is greatly influenced by the development of new technical methods and of new devices for measurement. With the growing complexity of science, the development of special techniques is of ever-increasing importance for the advance of knowledge.

Up to the year 1932, experiments on transmutation were confined to the use of α particles for bombarding purposes. It became clear that the process of transformation was in most cases complex, since groups of protons with different but characteristic energies were observed when a single element was bombarded. This led to the conception that discrete energy levels existed within a nucleus and that under some conditions part of

the excess energy was sometimes released in the form of a quantum of high frequency radiation.

The stage was now set for a great advance, and four new discoveries of outstanding importance were made in rapid succession in the period 1931–3. I refer to the discovery of the positive electron by Anderson in 1931, of the neutron by Chadwick in 1932, of artificial radioactivity by M. and Mme. Curie-Joliot in 1933 and of the transmutation of the elements by purely artificial methods first shown by Cockcroft and Walton in 1932.

The discovery of the neutron—that unchanged particle of mass nearly 1—was the result of a close study of the effects produced in the light element beryllium when bombarded by α particles. It is noteworthy that the proton and neutron, which are now believed to be the essential units with which all atomic nuclei are built up, owe their recognition to a study of the transmutation of matter by α particles.

Before the discovery of the neutron, it had been perforce assumed that nuclei must in some way be built up of massive protons and light negative electrons. Theories of nuclear structure became much more amenable to calculation when the nucleus is considered to be an aggregate of particles like the proton and neutron which have nearly the same mass. There was no longer any need to assume that either the positive or the negative electron has an independent existence in the nuclear structure. We are still uncertain of the exact relation, if any, between the neutron and the proton. The neutron appears to be slightly more massive than the proton, but it is generally believed, although no definite proof is available, that the proton and neutron within a nucleus are mutually convertible under certain conditions. For example, the change of a proton into a neutron within the nucleus should lead to the appearance of a free positive electron, while conversely the change of a neutron into a proton gives rise to a free negative electron. In this way it appears possible to account for the observed fact that either positive or negative electrons are emitted by a large group of radioactive elements to which I will now refer.

In the early experiments on transmutation by α particles, it was supposed that a stable nucleus was always formed after the emission of a fast proton. The investigations of M. and Mme. Curie-Joliot showed that in some cases elements were formed which, while momentarily stable, ultimately broke up slowly, exactly like the natural radioactive bodies. Most of these radioactive bodies formed by artificial methods break up with the expulsion of fast negative electrons, but in a few cases positive electrons are emitted. Since the presence of these radioactive bodies can be easily detected, and their chemical properties readily determined, this new method of attack on the problem of transmutation has proved of great value. Nearly a hundred of these radioactive bodies are now known, produced in a great variety of ways. Some arise from the bombardment by fast α particles, others by bombardment with protons or deuterons. As Fermi and his colleagues have shown, neutrons and particularly slow neutrons are extraordinarily effective in the formation of such radioactive bodies. On account of its absence of charge, the neutron enters freely into the nuclear structure of even the heaviest element and in many cases causes its transmutation. For example, a number of these radioactive bodies are produced when the two heaviest elements uranium and thorium are bombarded by slow neutrons. In the case of uranium, as Hahn and Meitner have shown, the radioactive bodies so formed break up in a succession of stages like the natural radioactive bodies, and give rise to a

number of trans-uranic elements of higher atomic number than uranium (92). These radioactive elements have the chemical properties to be expected from the higher homologues of rhenium, osmium and iridium of atomic numbers 93, 94 and 95.

These artificial radioactive bodies in general represent unstable varieties of the isotopes of known elements which have a limited life. No doubt such transient radioactive elements are still produced by transmutation in the furnace of our sun where the thermal motions of the atoms must be very great. These radioactive elements would rapidly disappear as soon as the earth cooled down after separation from the sun. On this view, uranium and thorium are to be regarded as practically the sole survivors in our earth of a large group of radioactive elements, owing to the fact that their time of transformation is long compared with the age of our planet.

It is of interest to note what an important part the α particle, which is itself a product of transformation of the natural radioactive bodies, has played in the growth of our knowledge of artificial transmutation. It is to be remembered, too, that our main source of neutrons for experimental purposes is provided by the bombardment of beryllium with α particles. The amount of radium available in our laboratories is, however, limited, and it was early recognized that if our knowledge of transmutation was to be extended, it was necessary to have a copious supply of fast particles of all kinds for bombarding purposes. It is well known that enormous numbers of protons and deuterons, for example, can be easily produced by the passage of the electric discharge through hydrogen and deuterium (heavy hydrogen). To be effective for transmutation purposes, however, these charged particles must be given a high speed by accelerating them in a strong electric field. This has involved the use of apparatus on an engineering scale to provide voltages as high as one million volts or more and the use of fast pumps to maintain a good vacuum.

A large amount of difficult technical work has been necessary to produce such high D.C. voltages and to find the best methods of applying them to the accelerating system. In Cambridge these high voltages are produced by multiplying the voltage of a transformer by a system of condensers and rectifiers; in the United States by the use of a novel type of electrostatic generator, first developed by van der Graaf. Professor Lawrence, of the University of California, has devised an ingenious instrument called a "cyclotron" in which the charged particles are automatically accelerated in multiple stages. This involves the use of huge electromagnets and very powerful electric oscillators. By this method, he has succeeded in producing streams of fast particles which have energies as high as the α particle ejected from radioactive substances. Undoubtedly this type of apparatus will prove of great importance in giving us a supply of much faster particles than we can hope to produce by the more direct methods.

It was at first thought that very high potentials of the order of several million volts would be required to obtain particles to study the transmutation of elements. Here, however, the development of the theory of wave-mechanics came to the aid of the experimenter, for Gamow showed that there was a small chance that comparatively slow bombarding particles might enter a nucleus. This theoretical conclusion has been completely verified by experiment. In the case of a light element like lithium, transformation effects can be readily observed with protons of energy as low as 20,000 volts. Of course, the amount of transformation increases rapidly with rise of voltage.

The study of the transmutation of elements by using accelerated protons and deuterons as bombarding particles has given us a wealth of new information. The capture of the proton or deuteron by a nucleus leads in many cases to types of transmutation of unusual interest. For example, the bombardment of the isotope of lithium of mass 7 by protons leads to the formation of a beryllium nucleus of mass 8 with a great excess of energy. This immediately breaks up with two α particles shot out in nearly opposite directions. When boron 11 is bombarded by protons, a carbon nucleus of mass 12 is formed which breaks up in most cases into three α particles. The deuteron is in some respects even more effective than the proton as a transmuting agent. When deuterons are used to bombard a compound of deuterium, previously unknown isotopes of hydrogen and of helium of mass 3 are formed, while fast protons and neutrons are liberated. The bombardment of beryllium by very fast deuterons gives rise to a plentiful supply of neutrons. Lawrence has shown that the bombardment of bismuth by very fast deuterons leads to the production of a radioactive bismuth isotope, which is identical with the well-known natural radioactive product radium E. Many artificial radioactive elements can be produced often in great intensity. For example, the bombardment of common salt by fast deuterons gives rise to a radioactive isotope of sodium. This breaks up with a half period of 15 hours, emitting not only fast β particles but γ rays at least as penetrating as those from radium.

It may well be that in course of time such artificial radioactive elements may prove a useful substitute for radium in therapeutic work. By these methods also, such intense sources of neutrons can be produced that special precautions have to be taken for the safety of the operators of the apparatus.

Sufficient I think has been said to illustrate the variety and interest of the transmutations produced by these bombardment methods. It should, however, be pointed out that transmutation in some cases can be effected by transferring energy to a nucleus by means of gamma rays of high quantum energy instead of by a material particle. For example, the deuteron can be broken up into its components, the proton and neutron, by the action of the gamma rays from radium or thorium. As a result of the bombardment of lithium by protons, gamma rays of extraordinarily great quantum energy as high as 17 million volts are strongly emitted. Bothe has recently shown that these high energy rays are able to transmute a number of atoms, neutrons usually being emitted in the process.

Some simple laws appear to hold in all individual transformations so far examined. Nuclear charge is always conserved, and where heavy particles are emitted, so also is energy when account is taken of the equivalence of mass and energy. Certain difficulties arise with regard to the conservation of energy in cases where light positive and negative electrons are emitted during transmutation, and there is still much discussion on this important question.

The study of the transmutation of matter has been extraordinarily fruitful in results of fundamental importance. In addition to the α particle, it has disclosed to us the existence of those two building units of nuclei, the proton and neutron. It has greatly widened our conception of the varieties of atomic nuclei which can exist in nature. Not only has it led to the discovery of about one hundred new radioactive elements, but also of several stable isotopes of known elements like ^{3}H, ^{3}He, ^{8}Be which had previously been unsuspected. It has greatly extended our

knowledge of the ways in which nuclei can be built up and broken down, and has brought to our attention the extraordinary violence of some of the nuclear explosions which occur. The great majority of our elements have been transmuted by the bombardment method and in the case of the light elements which have been most carefully studied a great variety of modes of transmutation have been established.

Rapid progress has been made, but much still remains to be done before we can hope to understand the detailed structure and stability of different forms of atomic nuclei and the origin of the elements. I can not but reflect on the amazing contrast between my first experiment on the transmutation of nitrogen in the University of Manchester in 1919 and the large-scale experiments on transmutation which are now in progress in many parts of the world. In the one case, imagine an observer in a dark room with very simple apparatus painfully counting with a microscope a few faint scintillations originating from the bombardment of nitrogen by a source of α particles. Contrast this with the large-scale apparatus now in use for experiments on transmutation in Cambridge. A great hall contains massive and elaborate machinery, rising tier on tier, to give a steady potential of about two million volts. Nearby is the tall accelerating column with a power station on top, protected by great corona shields—reminding one of a photograph in the film of Wells's "The shape of things to come." The intense stream of accelerated particles falls on the target in the room below with thick walls to protect the workers from stray radiation. Here is a band of investigators using complicated electrical devices for counting automatically the multitude of fast particles arising from the transformation of the target element or photographing with an expansion chamber, automatically controlled, the actual tracks of particles from exploding atoms.

To examine the effect of still faster particles, a cyclotron is installed in another large room. The large electromagnet and accessories are surrounded with great water tanks containing boron in solution to protect the workers from the effect of neutrons released in the apparatus. A power station nearby is needed to provide current to excite the electromagnet and the powerful electric oscillators.

Such a comparison illustrates the remarkable changes in the scale of research that have taken place in certain branches of pure science within the last twenty years. Such a development is inevitable, for, as science progresses, important problems arise which can only be solved by the use of large powers and complicated apparatus, requiring the attention of a team of research workers. If rapid progress is to be made, such team work is likely to be a feature of the more elaborate researches in the future. Fortunately, there is still plenty of scope for the individual research worker in many experiments of a simpler kind.

The science of physics now covers such a vast field that it is impossible for any laboratory to provide up-to-date facilities for research in more than a few of its branches. There is a growing tendency in our research laboratories to-day to specialize in those particular branches of physics in which they are most interested or specially equipped. Such a division of the field of research amongst a number of universities has certain advantages, provided that this subdivision is not carried too far. In general, the universities should be left free as far as possible to develop their own lines of research and encouraged to train young investigators, for it can not be doubted that vigorous schools of research in pure science are

vital to any nation if it wishes to develop effectively the application of science, whether to agriculture, industry or medicine. Since investigations in modern science are sometimes costly, and often require the use of expensive apparatus and large-scale collaboration, it is obviously essential that adequate funds should be available to the universities to cover the cost of such researches.

In this brief survey I have tried to outline the contributions to scientific knowledge made in India, and the needs of the immediate future if science is to play its part in the national welfare. While the study of modern science in India is comparatively recent and naturally much influenced by Western ideas, it is well to recall that India in ancient days was the home of a flourishing indigenous science, which in some respects was in advance of the rest of the world at that time. The study of ancient writings has discovered in recent years the extent and variety of these scientific contributions, which notably advanced the study of arithmetic and geometry. The researches of Sir Prafulla Ray have also brought to light the important advances made in metallurgy and chemistry. May we not hope that this natural aptitude for experimental and abstract science, shown so long ago, is still characteristic of the Indian peoples, and that in the days to come India will again become the home of science, not only as a form of intellectual activity but also as a means of furthering the progress of her peoples.

THE SKEPTICAL PHYSICIST

By Dr. PAUL R. HEYL
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THOSE of you who are acquainted with the history of science will recognize the source whence I have plagiarized the title of this article. In the middle of the seventeenth century the young science of chemistry was in a state which troubled the conscience of the Honorable Robert Boyle, whose interest in this science was life-long. There was a theory widely held at that time that all substances were composed of three primary principles—salt, sulfur and mercury. In "The Sceptical Chymist," published in 1661, Boyle combatted this idea, criticizing the experiments upon which it was based and pointing out among other things the difference between mixtures and compounds. Modern chemistry owes much to the pioneer work of Boyle, and his merits were not unappreciated by his contemporaries, who dubbed him "the father of chemistry and the brother of the Earl of Cork."

The term "skeptical" has an etymology from which its present-day meaning has widely departed. The Greeks applied the adjective σκεπτικός to a person who gave thoughtful consideration to matters which called for action or decision. The antithesis of such a skeptic was the person who acted on impulse or emotion. Perhaps because the judgment of the skeptic was so often adverse, he gradually became recognized as a chronic doubter or even as an iconoclast. It is possible, however, that these adverse opinions may have been due in many cases not to original sin in the skeptic, but to essential unsoundness in the subjects that he was called on to consider.

I like to think that Boyle used the term "skeptical" in its original sense, and in that sense I may be permitted to use it in the present discussion. It is as true now as when Victor Cousin said it, nearly a century ago, that "la critique est la vie de la science," and the history of science shows that situations arise at frequent intervals where the application of this principle is called for. When criticism is stifled, science is dead.

One of these situations confronts us at the present time and has called forth a protest from a skeptical physicist to which scientific men of all households of faith may well give attention, for though it is the science of physics that is immediately concerned, the situation involves the fundamental question of the attitude of the scientific man toward nature.

I refer to Dr. Herbert Dingle and his article on "Modern Aristotelianism," which appears in *Nature* for May 8, 1937. The replies, pro and con, to this article were so numerous and extensive that it was necessary to devote an entire supplement of *Nature* to them (June 12, 1937). It will, I think, be interesting and profitable to give a résumé of Dingle's article and of some of the replies to it.

Dingle's article may appear to have been inspired by published statements by Eddington and Milne, but between the lines there are some of us who can read sympathetically the story of a slowly growing skepticism which has finally burst all bounds.

The term "Aristotelianism," as Dingle uses it, does not refer so much to the doings and thinkings of Aristotle himself as to the habit of mind and the outlook upon nature of the medieval scholars who acknowledged the great Stagirite as their master. Orthodox science since Galileo's day has held that the first step in the study of nature is the observation of phenomena, from which we may pass by

induction to the derivation of general principles. The "Aristotelianism" to which Dingle refers, and which dominated the scholastic thought of the western world up to the seventeenth century, was the doctrine that there are general principles known *a priori* to the human mind apart from observation or sense perception.

For instance, Aristotle reasoned that a heavy body must fall more rapidly than a lighter one, and this *a priori* principle was accepted and believed by the Aristotelians for 2,000 years, until it was shown by experiment and observation that such was not the fact. As Emerson says, "Things are in the saddle, and ride mankind."

For three centuries this Aristotelian view of nature has been regarded, at least by scientific men, as dead. It is, therefore, as Dingle says, no light matter when we find in our own day a revival of Aristotelianism in the front ranks of science itself. As ground for this serious charge Dingle quotes statements by Eddington and by Milne.

Eddington[1] says: "There is nothing in the whole system of laws of physics that can not be deduced unambiguously from epistemological considerations. An intelligence unacquainted with our universe but acquainted with the system of thought by which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we have attained by experiment."

Milne[2] is somewhat more restrained and conservative when he says, "It is, in fact, possible to derive the laws of dynamics rationally . . . without recourse to experience."

Statements like these, coming from leaders in science, are indeed serious, and it will be interesting to see what their authors have to say in their own defense.

[1] "Relativity Theory of Protons and Electrons," p. 327.

[2] *Proc. Roy. Soc.*, A, 158, 329; 1937.

Eddington stands by his guns, remarking that the passage cited by Dingle has been likewise quoted "without its safeguards" by almost all the reviewers of his book. And what are these safeguards? Eddington makes it clear that the quoted passage must not be interpreted as the *a priori* basis of his philosophy, but is the unexpected conclusion at which he has arrived as the result of his investigations.

And what are these investigations?

Some years ago Eddington, by an abstruse mathematical discussion which he states did not involve any observational measurements, arrived at a figure for the mass-ratio of the proton and electron which was quite close to the accepted experimental results. Still later he calculated by a relativistic-wave-mechanics method that the total number of elementary particles in the universe is $2 \times 136 \times 2^{256}$. This result still awaits experimental check.

"After a rather extensive series of researches," says Eddington in his reply to Dingle, "I have found that a great part of the current scheme of physics is deducible by *a priori* argument." But he goes on to admit that "since we can have no *a priori* knowledge of an objective universe such results do not constitute knowledge of an objective universe." Just what they do constitute he does not make clear.

Milne, in his defense, takes much the same position as Eddington. Dingle's criticism of Milne was directed in part against his doctrine of "kinematical relativity," which is a study of the consequences of the assumption that the universe is, on the average, homogenous both in distribution and motion. In developing the consequences of this assumption Milne endeavored to avoid any empirical appeal and to develop the physics of the universe after the manner of a logical geometry based upon axioms or space-definitions. In carrying out this development Milne appears to have made the

same discovery as Eddington. Milne remarks that it is an astonishing thing to find that the elimination of empirical appeal, including all appeals to quantitative laws of physics, can be carried as far as it can; and that with the elimination of such empirical appeals regularities emerge which play the part of the very laws of nature which are observed to hold good.

Milne admits that his resulting logical structure may not correspond to nature any more than do the various hypergeometries that have been invented, but says that just as results of value have followed from the development of such non-realizable abstractions as a four-dimensional cube, so it may be valuable to construct an abstract physics for its own sake.

This is a reasonable defense. As long as the limits of such investigations are clearly recognized, and they are held strictly within these limits, they may be as valuable and stimulating as any other scientific speculations. But the essence of Dingle's criticism is that this line of action can be carried to such excess and be given such a color as to deceive the very elect. When those to whom we look for scientific leadership can say, in effect, "Don't experiment; calculate! It is easier, cheaper, more exciting and productive of results," then science is on its way back to the Aristotelianism of the Middle Ages.

The ability of a theory to calculate and predict phenomena is an asset of undoubted importance, but it is not enough, and must not be over-rated. A modern instance of this is Bohr's theory of atomic structure. The flexibility and accuracy with which the Bohr atom adjusted itself to the manifold conditions required by the periodic law of the elements were remarkable. The Bohr theory moved along with regular steps, dropping the right element into each empty compartment provided by the periodic law. When it came to the rare earths the theory halted for a moment, dropped exactly the right number of elements all into the same compartment, and then resumed its measured tread, dropping one element at each step until all were put in their proper places. No wonder that Whetham characterized this behavior as "satanic." Yet with all this to its credit the Bohr atom, because of its failure to meet three requirements, had to give place to a still more adaptable theory as soon as one could be found.

The theory of relativity is in a similar position to-day. It has done much; it has explained one astronomical puzzle for which the Newtonian law of gravitation was inadequate; it has predicted two other physical phenomena whose existence has been experimentally verified; but when it comes to such a simple matter as centrifugal force, then, as Eddington himself says, the theory stops explaining phenomena and begins explaining them away. The theory of relativity holds its own to-day only because no one has as yet been able to devise a better.

The failure of a theory for reasons of this character need reflect no discredit upon its author. We can still admire a theory which has marked a step in progress, which has been able to cut a little more closely to the line than any which preceded it, even though it be soon superseded by a better. But some theoretical researches in modern physics fall into a different category, and tend to make the skeptical physicist a little more skeptical.

These researches are for most of us difficult reading. Perhaps this is unavoidable, considering the nature of the subject. We of the rank and file must frequently take the results of our leaders on faith; and unfortunately we sometimes find in those portions which we can understand that which seriously shakes our confidence in the parts that we can not follow. When, for example, Edding-

ton[3] says that the mass of the sun is 1.47 kilometers, and repeats this in the second edition of his book, and when Minkowski[4] points with pride to what he calls "the mystic formula," 3×10^5 km $= \sqrt{-1}$ sec, and when it requires no knowledge of the calculus of tensors to see what the trouble is, the only conclusion possible is that the fundamental principles of mathematics and physics are like the laws of whist—for beginners to observe and for masters to disregard.

Minkowski's memoir on "Space and Time," in which this "mystic formula" occurs, has long enjoyed the reputation of a classic. It antedates Einstein's general theory of relativity by seven years, and in his paper of 1915 Einstein acknowledges his debt to Minkowski. Minkowski's memoir contains the concepts of the four-dimensional space-time continuum, of world lines and of space-like and time-like vectors, upon which basis has been erected a vast structure of relativistic cosmology. With this "mystic formula" staring us in the face it will be interesting to examine the philosophical basis of Minkowski's theory.

The fundamental idea of the memoir is that time in some way bears a fourth-dimensional relation to our solid space. Now, of course, time has not the dimensions of a length, but if we multiply it by a velocity that defect disappears. Minkowski multiplies the time t by the velocity of light c, thus obtaining the length ct, which may be used as a fourth dimension. Unfortunately, it happens that an important equation resulting from this hypothesis is not symmetrical.

Now every mathematician has in him something of the artist; an eye for symmetry, for beauty of results and for elegance in the methods used in obtaining them. Now an unsymmetrical equation offends the artistic sense; in addition, it is scientifically undesirable, as results can not be obtained from it as readily as from a symmetrical form. And here Minkowski had a brilliant idea. If we multiply the fourth dimension ct by $\sqrt{-1}$ the unsymmetrical equation becomes symmetrical.

Of course this gives us a set of four axes, three of which are real and one imaginary, but any difficulty attaching to this detail is soon forgotten in the dazzling light of the brilliant results that begin to appear. For example, referred to our new coordinates, the complicated Lorentz transformation appears as a mere rotation of the axes—which, however, involves the turning of the imaginary axis through an imaginary angle.[5] Whether this makes the Lorentz transformation any more comprehensible is a question—which the artist-mathematician answers in the affirmative.

$\sqrt{-1}$ has a legitimate application in pure mathematics, where it forms a part of various ingenious devices for handling otherwise intractable situations. It has also a limited value in mathematical physics, as in the theory of fluid motion, but here also only as an essential cog in a mathematical device. In these legitimate cases, having done its work it retires gracefully from the scene; but to make an imaginary quantity a permanent foundation stone for a physical hypothesis is, as they say in Ireland, a white horse of another color.

There is no denying the potency of $\sqrt{-1}$ as a useful tool. As an illustration, I may point out how it helps us to an

[3] "Report on the Relativity Theory of Gravitation," second edition, 1920, p. 50.

[4] "Raum und Zeit," an address before the German Convention of Natural Scientists and Physicians, Cologne, September 21, 1908. *Phys. Zeitschrift*, Vol. X, p. 104, 1909. English translation in "The Principle of Relativity; memoirs by Lorentz, Einstein, Minkowski and Weyl," New York, Dodd, Mead and Co., 1923.

[5] Minkowski discusses this point very briefly. The complete mathematical treatment is given by Eddington in his "Report on the Relativity Theory of Gravitation," second edition, 1920, page 14.

interesting little theory of gravitation. Einstein, in discussing the resemblance between inertia and gravitation, considers the case of a revolving circular platform. Suppose such a disk large enough to hold an observer, and let it be covered by a dome so that the observer within can not tell by direct observation of outside bodies whether the disk is in motion. Let the disk be at rest. The observer, in moving from one place to another in his little world, would notice no difference between one point and any other. Let the disk be now set in rotation. The observer, unless he stood at the center of the disk, would experience a force urging him radially outward, and the farther he was from the center the greater would be this force. He would, in fact, be living in a sort of turned-inside-out gravitational field.

As a theory of gravitation there are two defects in this. The force increases with the distance from the center; and it is in the wrong direction, outward instead of inward. The first of these defects is quite easy to remedy. We may suppose the speed of rotation of the disk to be variable, governed either by a mechanical device or by a watchful engineer so that the speed will increase as the observer approaches the center, and will diminish as he nears the circumference.

The other defect is not so easy to dispose of. It is obviously useless to give the disk a negative velocity of rotation, as the centrifugal force depends on the square of the velocity. But if we multiply the velocity not by -1 but by $\sqrt{-1}$, the trick is done.

Everybody laughs at this; nobody laughs at Minkowski. Yet I have done nothing but what Minkowski has done. I have turned my disk through an imaginary angle; Minkowski turned his axes of coordinates through an imaginary angle. The trouble is that I have made my illustration so simple that any one can see through it. Had I made it as abstruse as Minkowski's memoir it might have been received with equal seriousness. Truly, as Dingle says, the criterion for distinguishing sense from nonsense has been lost; our minds are ready to tolerate anything, if it comes from a man of repute and is accompanied by an array of symbols in Clarendon type.

And yet we must not be too hard on $\sqrt{-1}$; it may stand us in good stead on occasion, as is instanced by a tradition of the National Bureau of Standards.

In the early days of the Bureau, when the staff was smaller, and there were no official guides, the staff-members took turns in conducting parties of visitors through the laboratories. On one such occasion the visitors were shown some liquid air, and they asked, "What is this used for?" In those days liquid air had not yet found any practical application, and was merely a scientific curiosity. The guide, who tradition says was one of the lady-members of the staff, was rather non-plussed for the moment, but quickly recovered her presence of mind, and replied, "It is used to lubricate the square root of minus one."

I sometimes think Minkowski must have heard that story.

NEED FOR RESEARCH ON GRASSLANDS[1]

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OCEANS, forests and deserts stir the minds of men. The vastness and power of the ocean, the grandeur and hidden depths of the forests and the extreme conditions of the desert appeal to the imagination. Yet to the uninitiated grassland is monotonous in its seeming uniformity over wide vistas: the distant horizons are unbroken, the "plains" are endless. In past times settlers hesitated before leaving the forest behind to enter the grasslands or "barrens" where fuel and building materials were lacking and the elements, especially wind and sun, held full sway. Man is not originally an animal of the plains but rather a creature of the forests or, at least, of the margins of the forests. Knowledge of the grassland, acquired often only through deeply felt or painful experience, leads to appreciation of the widespread, the uninterrupted view and the fertile soil, or perhaps to despair at recurring droughts and persistent, drying, hot or freezing winds.

Oceans, forests and deserts deserve all the attention they receive. On the other hand, grasslands have been strangely slighted; they demand greater attention from the points of view not only of practical economics but also of evolutionary and ecological thought. Grasslands conceal vast unexplored stores of scientific facts which, when brought to light, will enrich the fields of plant and animal ecology, evolution, climatology, geography and geology. The knowledge to be gained from them may contribute significantly to the solution of problems concerning the evolution of grassland plants and animals; the influences of diverse environments, from tropical lowlands to deserts and alpine summits, upon distribution and origin of species; the results of interrelations between plants and animals under widely varying environments; the linkage of present geographic distributions and characteristics of grassland species to forest, aquatic and desert species and to earlier geological species and conditions. Study of the teeming life along the seacoasts began with the Greeks and is continued to-day in numerous marine laboratories with results of unquestioned significance to biological science and human welfare. Investigations in the generally neglected grasslands may be fully as fruitful in contributions to the needs of our civilization. The analysis and correlation of great stores of data secured from seas and lakes, from forests and deserts, and from the grasslands are essential to the formulation of sound concepts and principles in numerous fields of learning. Especially is there need for this study of grassland faunas. We now use these lands for grazing domestic animals in enormous numbers, although we have never made the requisite basic studies of the relations of native grassland faunas to grasses. In actual fact we have so over-utilized the grasslands that now, when we are compelled to face the necessity of fundamental research, we find ourselves with practically no such lands in original condition for investigations.

[1] Prepared for the Committee on Ecology of Grasslands of North America of the National Research Council. The writers are indebted for numerous suggestions to Dr. V. E. Shelford, chairman of this committee, and Dr. R. E. Coker, chairman of the Division of Biology and Agriculture, National Research Council, Washington, D. C.

The significance of grasslands becomes much more apparent when we learn of their vast extent and diverse aspects. About three fourths of the earth's surface is covered with water. Of the remaining one fourth, some 52 million square miles, about 42 per cent. is classified as grassland, about 33 per cent. as forest and 25 per cent. as desert. The grasslands, then, have a total extent far exceeding that of either forest or desert and approaching half of the total land area. In the United States about 38 per cent. of the total land area of 1,903 million acres was originally grassland. Sixteen per cent. of the total land area was tall grass, or prairie; 14 per cent. short grass or plains; and 8 per cent. other types of grassland, as marsh, alpine meadow and desert grassland. Of these great areas almost nothing remains as it was, either floristically or faunistically, to teach us lessons of basic importance in the perpetuation of a most valuable resource. That the grasslands have been largely mismanaged as to the grasses is now widely known; that they have been mismanaged as to their animal inhabitants is just beginning to be realized.

J. W. Bews presented a few years ago a theory of ecological evolution of grasslands based upon facts derived from geographic distribution, from fossil botany, from the taxonomic characteristics of tribes, genera and species of grasses and from the environmental characteristics of habitats of grasses. Bews emphasized that the theory is incomplete for lack of sufficient data. The theory is nevertheless a valuable one because it integrates facts from various fields to give a natural classification of grasslands. The most primitive grasses, such as the Bamboos, are associated with tropical forests and forest margins. The woodland grasses of temperate regions are slightly more advanced. More highly developed are the grasses found in the chaparral type of woodland such as is found in the vicinity of Berkeley, Calif. The grasses of marsh and stream-bank are closely related both floristically and ecologically to those of forest margins, and the aquatic grasses probably originated from the former. Grasses characteristic of saline soil are connected with aquatics and with sand-loving grasses. The latter are connected with nearly all the classes mentioned, since it is but a short step from grasses with trailing stems which root at the nodes, as found in forest edges, to the sand binders with subterranean traveling stems.

According to Bews, fossil evidence supports the view that the primitive grasses were species with high moisture requirement, such as those found in tropical forest margins. The larger tropical and subtropical bunch-grasses, found in extensive savannas, probably developed from tropical forest margins through the intermediate stage of tropical high grass savannas. Higher in tropical mountains alpine grasses developed from bunch-grasses. The extensive temperate grasslands, prairies and plains were formed by grasses that originated from species of temperate woodland and stream-bank. The arid species of semideserts and deserts are closely connected with sand and salt grasses and these are among the most highly developed of all species of grass. We see then that, geologically speaking, the large grass areas of the world are recent creations.

In all probability the evolution of major species of animals was contemporaneous with the evolution of grasslands. In the well-known evolution of the horse there are found all stages of change from a small forest animal to the magnificent beast of the plains, which finally became one of man's most important domestic animals in the Old World. In the meantime it mysteriously disappeared from the Western Hemisphere, although its reintroduction has proven its continued adaptation to the grasslands which, fol-

lowing the Spanish conquest, it quickly overspread.

No less significant and interesting were the development of the camel, bison, antelope, coyote, buffalo wolf, jackrabbit and many lesser species. Now most of these have nearly disappeared before man, the arch-destroyer, while others, such as the jack rabbit and some smaller rodents, have enormously increased, doubtless in some cases as a direct result of man's ill-judged activities.

The rounding out of this story of the evolution of grasslands requires the collection and analysis of facts from many study centers in prairies and plains, marshes, meadows and savannas, and alpine, arctic and tropical regions. In these centers detailed studies and analyses of the plant and animal populations and of their relations to one another and to the environment should be continued over a long period of years and supplemented by precise studies of geographic distribution and paleontological data. Grassland investigations of a quantitative nature, continued over many years in one location, are absolutely essential to furnish the fundamental facts upon which to build theories of evolution, such as that of Bews, and biological concepts and principles in general.

Land planning must remain inadequate, short-sighted and wasteful of biological and soil resources until there is much more complete knowledge of grasslands and their fauna than we now possess. In spite of this great need for dependable facts and principles there is now no provision in the United States for studying grasslands in a thoroughly basic manner over a long period of years. This kind of study requires setting aside for a long period of time tracts of adequate size for the sole purpose of acquiring thorough knowledge of grasslands; it requires, in addition, suitable support for a competent staff of investigators.

Grasslands are widely distributed in North America. They extend from the aspen park lands of Alberta, Saskatchewan and Manitoba through the prairie and plains states into southern Mexico, from Ohio to Washington, Oregon and California. The prairie lands are broken in the east by deciduous forest and in the west by coniferous forest and desert. Marshes border the seacoasts and lakes, and sand grasslands are dotted over the country. Several classifications have been made of these wide-spread grasslands, but all of them are based upon fragmentary data. A natural classification can not be completed until much additional information has been secured from intensive, long-continued investigations. The tall-grass grassland or prairie, extending eastward from the 97th and 98th meridians and originally occupying seven-eighths of Iowa, for example, is unique in being the largest area in the world of this type of fairly moist grasslands. Leading dominants are the bluestems, needle-grass, dropseeds, panic grasses and wild rye. West of the prairie and extending to the eastern limits of the Rocky Mountains occur the mixed prairie and plains, or short-grass grasslands, comparable to the steppes of Russia. Restriction of moisture mainly to the surface two feet, droughts and high winds are inimical to tree growth, but the dominant grama grasses, buffalo grass, wheat grasses and low sedges are adapted to these rigorous conditions. The desert grasslands, extending from southwestern Texas through southern New Mexico into Arizona and Mexico, dominated by several species of grama grass, three-awn grass and mesquite grass, is adapted to even more severe aridity. Extensive areas in valleys and foothills in California and Lower California, formerly dominated by bunch grasses such as needlegrasses, June grass and wild ryes, have been replaced, following overgrazing and fire, by annual weeds such as wild oats, ripgut, foxtail chess and wild barleys. The productiveness of the Pa-

Photo by Herbert C. Hanson

BORDERLINE AND TENSION OR COMPETITION ZONE BETWEEN TWO GRASS COMMUNITIES

A PUCCINELLIA-DISTICHLIS COMMUNITY ON THE LEFT MEETS A SPARTINA-PANICUM COMMUNITY ON THE RIGHT. KILLDEER, NORTH DAKOTA. COMPETITION AND MIGRATION STUDIES ARE NEEDED.

Photo by Herbert C. Hanson

THE DEVELOPMENT OF A STABLE COMMUNITY FOLLOWING EROSION OF A SMALL BUTTE

LARGE AREAS ARE NEEDED FOR STUDIES OF SUCH PROCESSES.

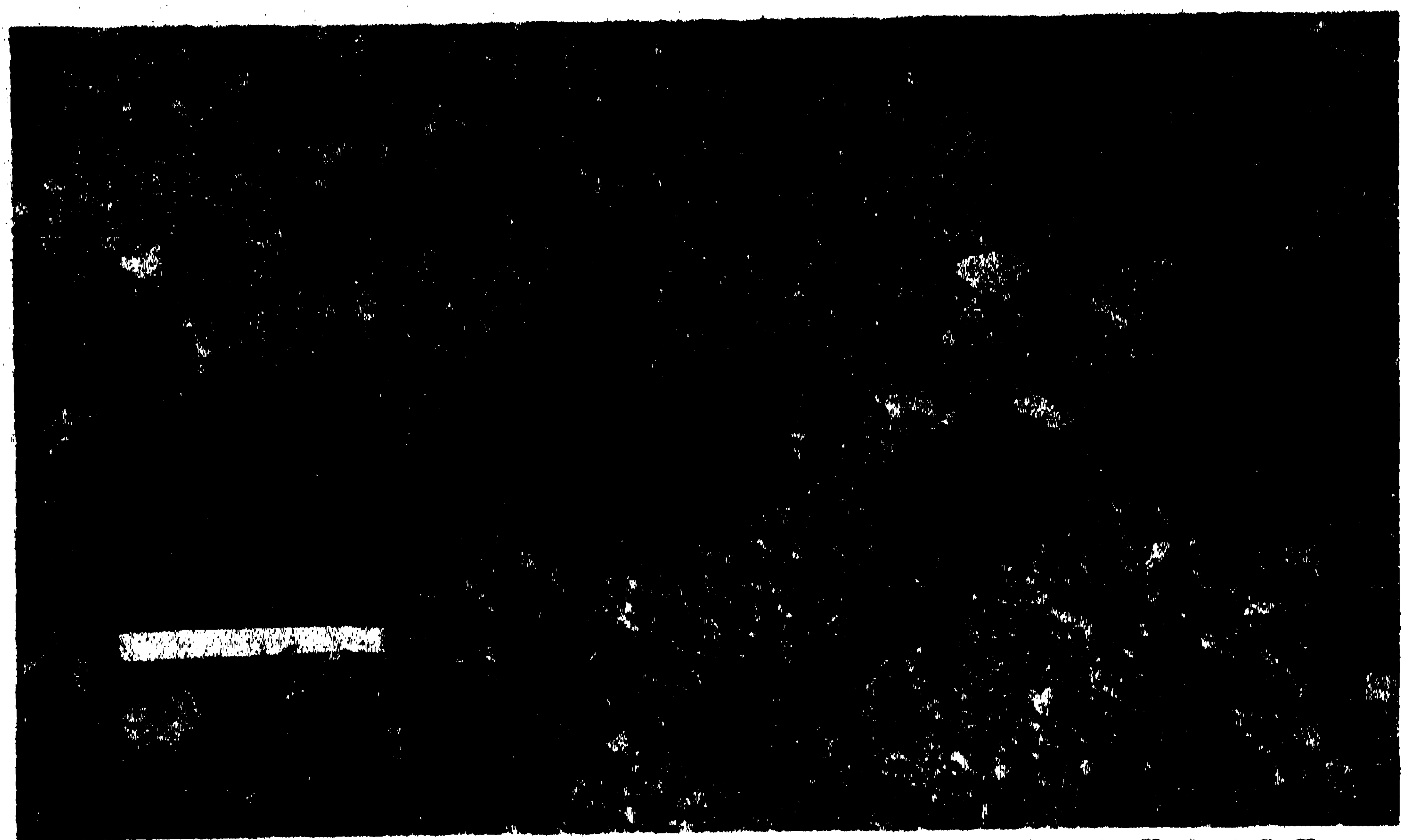


Photo by Herbert C. Hanson

SUCCESSION OR THE DEVELOPMENT OF A PLANT-ANIMAL COMMUNITY

NATURAL IMPROVEMENT OF LAND ON THE PLAINS IN NORTHEAST COLORADO THROUGH THE INVASION OF A BARE AREA BY MATS OF ARENARIA HOOKERI IS SHOWN. HOW MUCH TIME IS REQUIRED TO PRODUCE GRASSLAND? IT INVOLVES MIGRATION OF PLANTS FROM DISTANCE AND THE QUESTION OF THE INFLUENCE OF ANIMALS ARISES. LONG-TIME STUDIES ON LARGE AREAS UNDER PROTECTION ARE NEEDED TO ANSWER SUCH QUESTIONS.

louse wheat lands is due largely to the bunchgrasses, including bluebunch wheat-grass and sheep fescue, the dominants in the Palouse prairie which formerly occupied an extensive area in eastern Washington and Oregon, northern Utah and southern Idaho.

Little effort has been made to use grasslands in their original condition. Aided by the "Westward Ho" movement, by the lack of a constructive land policy, by the expansion in power farm machinery and the demand during the world war for more wheat, there has been a scramble, at times a frenzy, to "break" the sod. This drive to settle the West and plow up the grassland did not stop until millions of acres were turned "wrong side up" and the dust clouds, blown from these lands, reached the Atlantic seaboard. Now, after a large part of our grasslands have been wasted, interest is being shown in this natural resource and we begin to appreciate its value. The immediate and insistent demand is to get the land back into grass; but to restore is no easy matter. Nature required thousands of years to produce these grasslands which, as they existed before breaking up and consequent erosion, were the result of countless interactions of plants, animals and climatic and soil conditions. The best that can be done now is to try to adjust human operations to nature's processes and requirements. Reseeding will aid in the hastening of invasion; but much more is necessary. In man's struggle with the environment there are two alternatives; he must either change unfavorable factors so that they will be more favorable to his well-being or he must adjust himself to these factors. This law operates in man's relations with grasslands, which in many places have now gotten out of control in consequence of mismanagement. Man made a serious mistake when he attempted to make all grassland more favorable to his well-being

by plowing, draining, burning, overgrazing, etc. He has learned that to avoid greater evils much land must be restored to grasses. He may have learned also that he must adjust himself to the needs and ways of grasslands and grassland animals if he is to survive in grassland country.

There's the rub. How can man adjust himself to something that he knows so little about? Fundamental scientific research has been very limited. Most of the investigations have been prompted by practical questions which demanded early answers, such as: What is the grazing capacity of this area? What class of live stock is this range suited to? How can the density of desirable forage plants be increased? How can undesirable species, poisonous plants and destructive animals be eliminated? Elimination of certain animals has been atempted empirically without the requisite basis of knowledge, although it now begins to appear that in many instances proper management of the areas would suffice for the control of species that are objectionable only in excessive numbers. Usually only spasmodic and short-lived study has been given to such fundamental topics as these: the origin of grasslands; the quantitative composition of the flora and fauna and its variability in relation to season; the influence of climatic and soil conditions upon botanical composition; the interrelations of plants and animals; the rate of soil building by various types of grasslands; the interrelations of such ecological processes as competition, reaction and succession. Dr. J. E. Weaver, of the University of Nebraska, has carried on research in these subjects in the vicinity of Lincoln, Nebraska, since 1915, and he was preceded by Dr. F. E. Clements and Dr. Charles Bessey, who laid foundations in the nineties. This is the only place in the United States where long-continued fundamental studies have been conducted consistently. In consequence, the prairies of eastern Nebraska are understood better perhaps than any other natural grasslands in the world. It is most regrettable, however, that these studies have been dependent upon such year-to-year arrangements as could be made with the owners of the study areas. There has been the continuous threat that the owners would plow up the prairie instead of mowing it for hay. Many desirable experiments could not be conducted because the investigator did not have complete control of the areas under study. The U. S. Forest Service has studied grasslands in various parts of the West for many years, especially in southern New Mexico, southern Arizona and in the mountains of Utah. The Forest Service studies have primarily the practical purpose of developing grazing methods that will maintain maximum yields of forage, produce live stock most effectively, and be in harmony with other forest uses such as the protection of watersheds. The investigations of a federal government agency such as the Forest Service, as well as those of many state experiment stations, must, in order to secure annual appropriations, provide answers to the immediately practical problems pressed upon them by their constituents. Unless the rancher receives information or help on how to decrease death losses due to suspected poisonous plants, what to seed on an abandoned field or, in short, how to produce more efficiently and to market more effectively, he is likely to take advantage of the opportunity to decrease his taxes a mite by withdrawing his support for these experimental agencies. Under such conditions it is extremely difficult to conduct a research program on a broad and fundamental basis which requires long and certain tenure of suitable land, adequate equipment and personnel and freedom from the pulling and pushing of political factions and the pressures of narrow-minded groups that have special axes to grind.

The desert studies and other investiga-

Photo by Herbert C. Hanson

POCKET GOPHER MOUNDS FURNISHING BARE AREAS FOR INVASION OF WESTERN WHEATGRASS

THE HETEROGENEITY OF PRAIRIE VEGETATION IS INCREASED. MUCH MORE WORK IS NEEDED ON LARGE AREAS TO DETERMINE THE RÔLE OF ANIMALS.

tions conducted by the Carnegie Institution of Washington indicate the kinds of research needed for the grasslands. They attack fundamental problems concerning the nature of the desert. The Desert Laboratory at Tucson, Arizona, is devoted primarily to this task; the view-point is wide and inclusive; the desert is considered in its widest relations to the environment. Intensive, as well as extensive, studies have been under way for a number of years. These basic studies are leading to a more complete knowledge of the desert fauna and flora and physical environment, and the knowledge gained serves with increasing value as a reservoir of facts and principles for the solution of practical problems. They are demonstrating that the most practical kind of investigation is fundamental research because it discloses basic facts upon which generalizations and principles may be built. Upon this wide and deep foundation of knowledge not only may an enormouse superstructure of scientific land use be erected, but also science and civilization in general may be advanced.

Notwithstanding that during the past thirty-five or forty years a great deal of study has been given to many of the phases of this complex subject by competent and painstaking investigators in widely scattered regions of great climatological variety, the surface of the subject as a whole can scarcely be said to have been more than scratched. Moreover, it would seem that, if the work of a group of different investigators could be coordinated, integrated and fitted into a common pattern covering a field limited to desirable proportions, much more valuable results would be attained than can possibly be secured from isolated individual efforts, however competent and painstaking they may be.

Such a thought as this occurred some

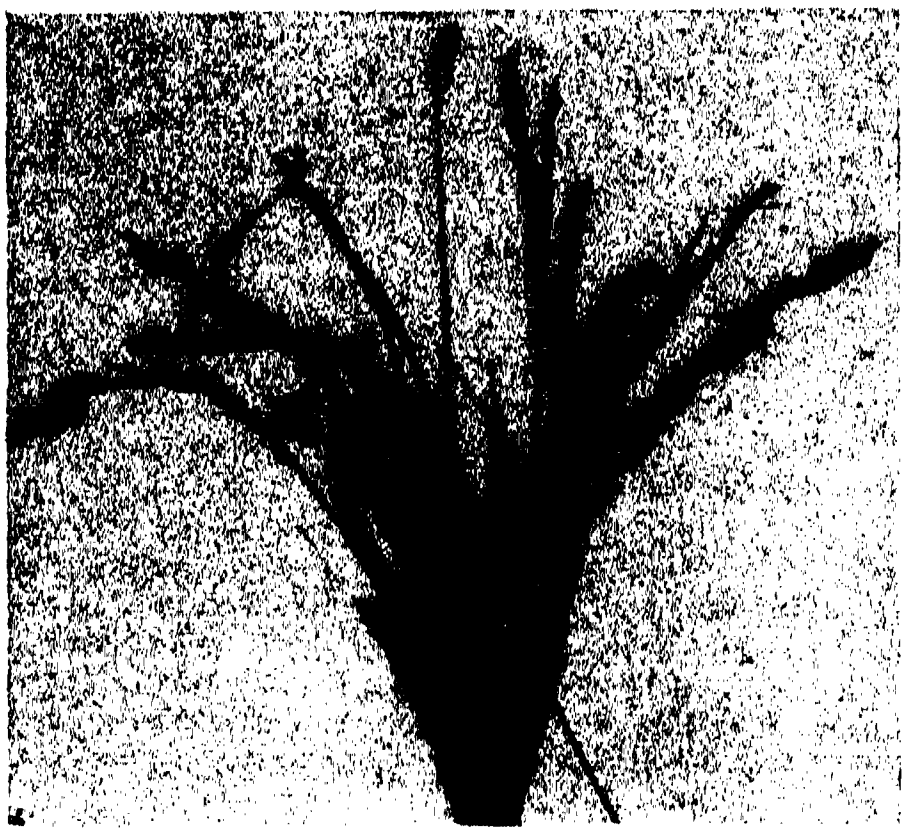


Photo by D. Anderson—Fargo, 1932
—Legend by J. A. Munro

DEAD GRASSHOPPERS ATTACHED TO GRASSES KILLED BY A WEATHER-CONTROLLED DISEASE

THIS FUNGUS DISEASE (EMPUSAE GRYLLI) ACCOMPLISHED NEARLY 100% KILL OF GRASSHOPPERS IN SMALL LOCALIZED AREAS WHERE HUMIDITY WAS HIGH. THE DYING HOPPERS ALWAYS CLIMBED TO THE TOP OF WEEDS BEFORE BEING OVERCOME BY THE DISEASE. HERE THEY REMAINED ATTACHED UNTIL REMOVED BY WEATHERING AGENCIES.

years ago to certain members of the Ecological Society of America. It appeared to them also that the great grasslands of North America, stretching from Saskatchewan to the Gulf of Mexico, would be particularly favorable for coordinated study. Accordingly a Committee for the Study of the Ecology of Grasslands was established by the society at the Cleveland meeting in 1929 and assigned the task of finding ways and means of effecting such an organization as would make possible the practical realization of the idea. Through the work of this committee the National Research Council became interested two years later and since then the committee has been sponsored in its endeavors by both the Ecological Society and the National Research Council. Under the competent and vigorous leadership of Dr. V. E. Shelford, who has done a prodigious amount of personal work, the committee has held a meeting at every subsequent Ecological Society meeting; it has held three regional meetings (Texas, June, 1933; North Dakota, June, 1935; Nebraska, June, 1937) and, in addition, has exchanged ideas and formulated principles continuously by correspondence. As a result of these deliberations, confidence in the soundness of the idea of cooperative, coordinated research has become stronger in the minds of all the committee members.

As desirable phases of the proposed study a recent report of the committee suggests the following, which it believes to embody a very high degree both of scientific merit and of practical applicability. Reasons for each subject of study recommended are briefly stated.[2]

(1) *Study of life history and habits of individual grassland plants and animals.*

[2] The numbered paragraphs were prepared by the committee during its 1935 meeting at Dickinson, N. D.; see 1935 Report, Part II, p. 11—deposited with the Division of Biology and Agriculture, National Research Council, Washington, D. C.

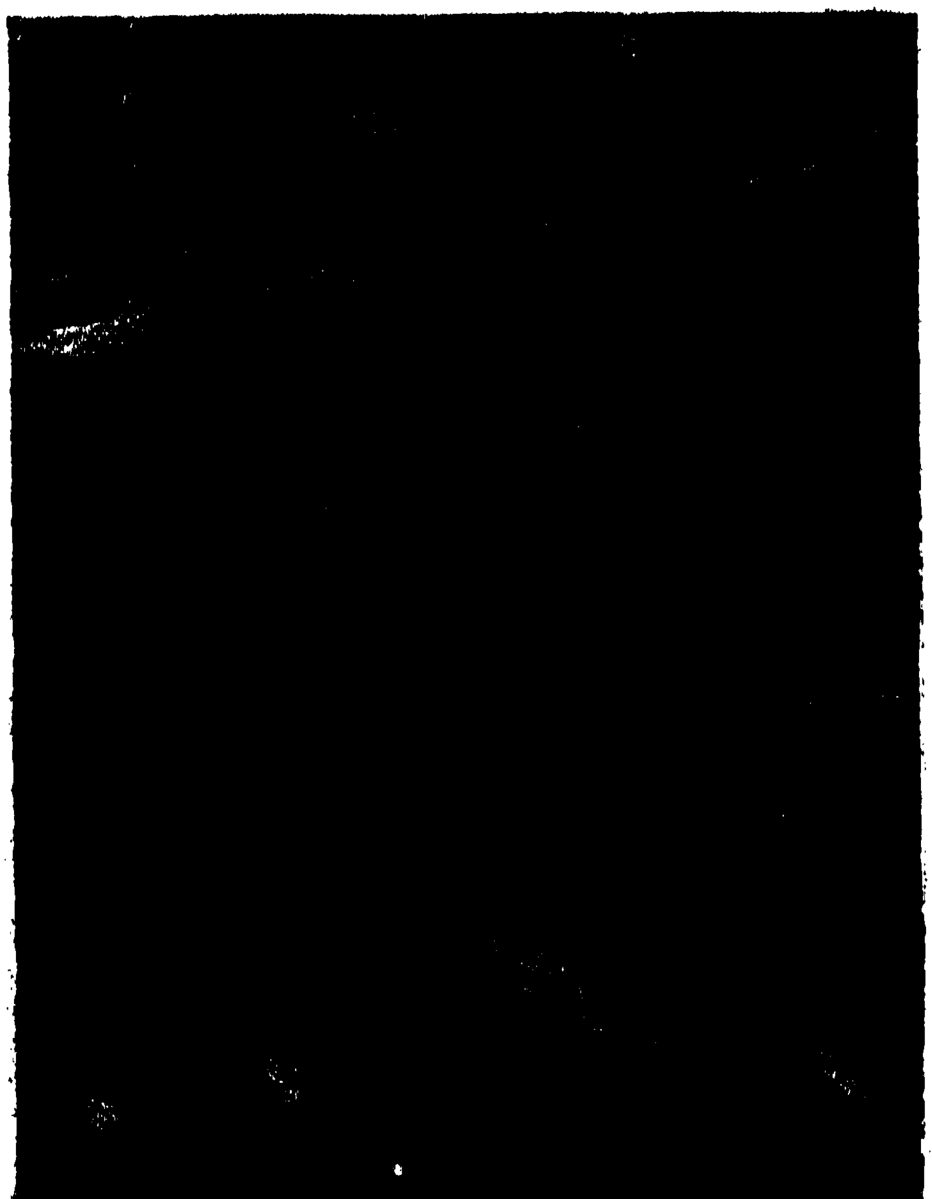
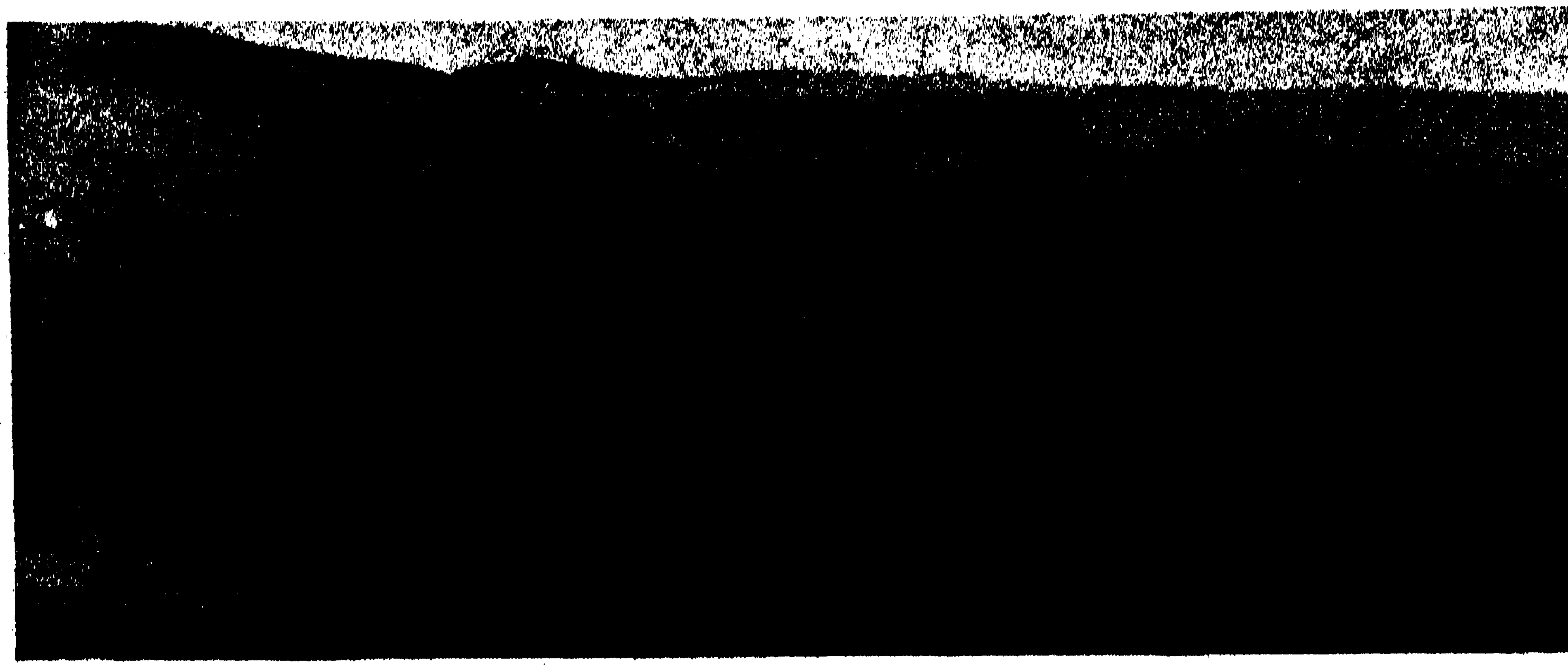


Photo by Elliot Blackwelder

GRASS IS MUCH REDUCED; SAGEBRUSH HAS INVADED

THE PRAIRIE MOUND-BUILDING ANT PERSISTS. ANTS AND RODENTS, NOT EARTHWORMS, ARE THE CHIEF SOIL WORKERS IN GRASSLAND. EASTERN WYOMING.



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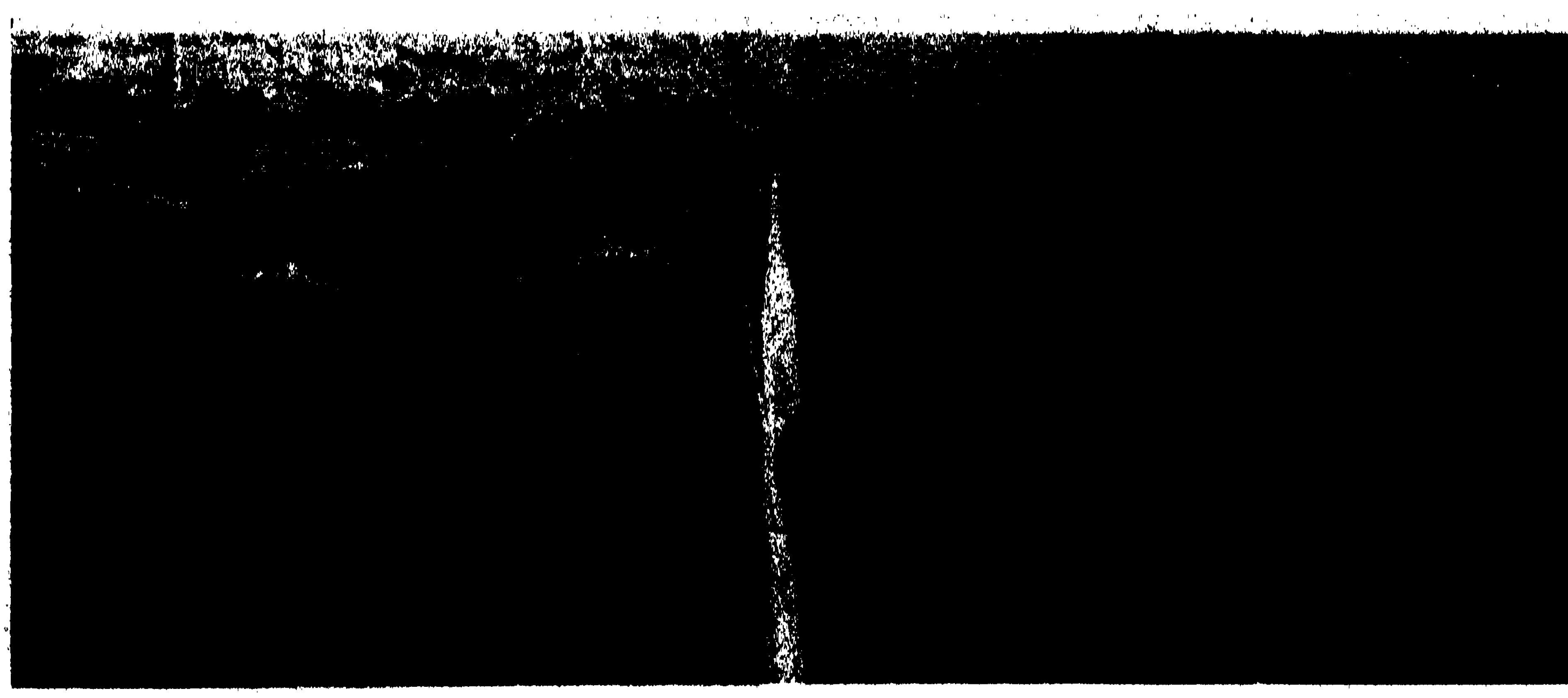

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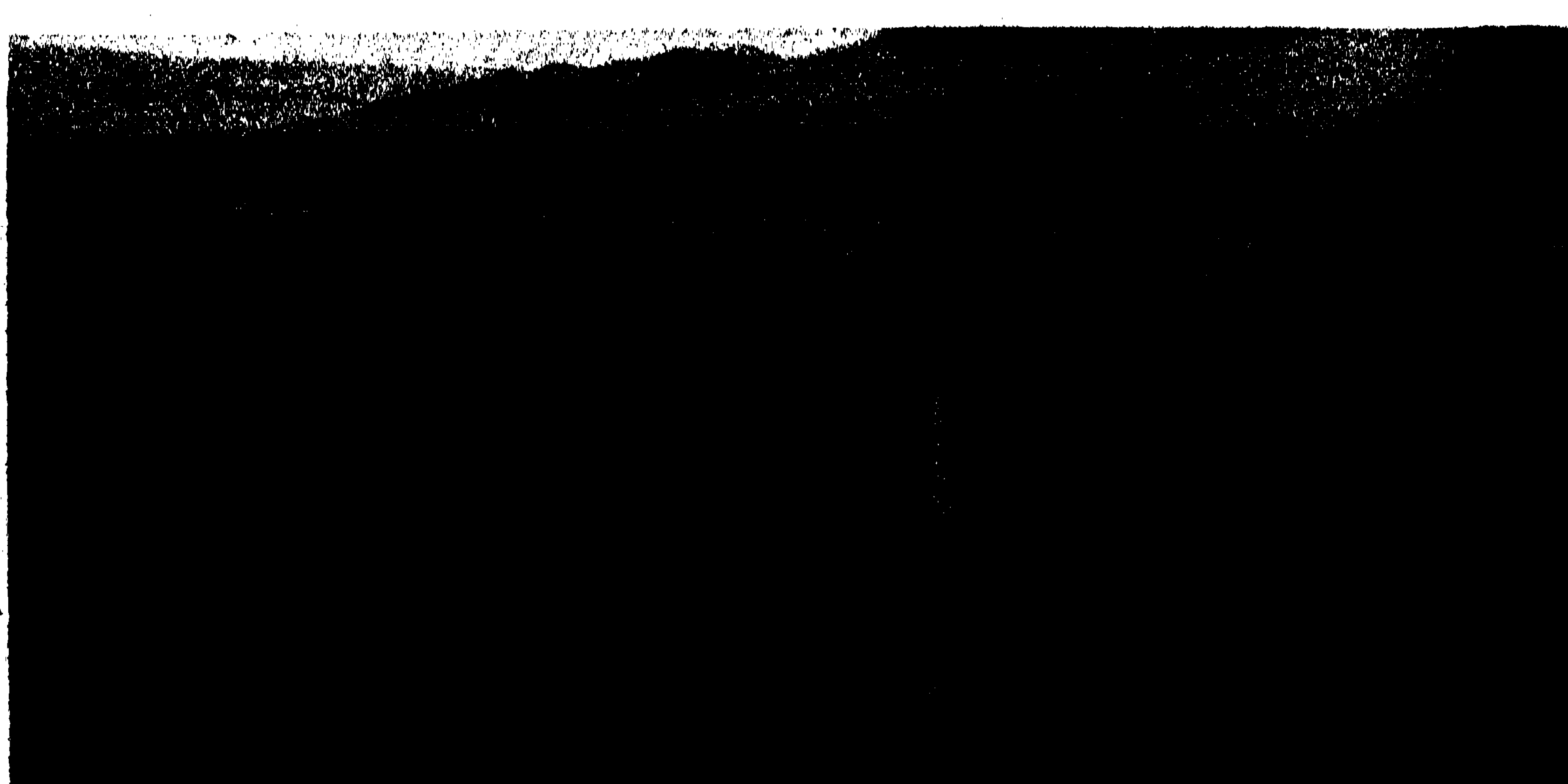


Photos by Herbert C. Hanson

C

SO-CALLED DESERT REVEALS ITS GRASSLAND CHARACTER

Knowledge of the life history and interrelationships of range plants and animals is meager. With plants there is vital need for further information on vegetative growth, methods and rate of dissemination, seed collections, etc. With animals detailed life histories and ecological and soil relationship studies are much needed. More serious than any other deficiency, perhaps, is the lack of information on plant-animal interrelationships, on food-chains, plant and animal succession, phenological features, factors influencing distribution and numbers of both plants and animals. The solution of these problems, affecting the biota as a whole and not plants or animals alone, is of extraordinary significance and permanent importance to the maintenance and increase of vital grassland values in soils, water, forage and wildlife.

(2) *Study of the processes of biotic communities, such as invasion, competition, association and succession.* Because of the lack of control of experimental areas and the insufficient duration of experiments, information on these processes is also meager. It is through these processes that eroded areas become revegetated, that over-grazed areas are rejuvenated and soil fertility restored. Only by studies of conditions in undisturbed areas can adequate controls be provided for experiments involving recovery.

(3) *Study of the relation of plants and animals to soil building, soil improvement, and soil binding.* This aspect includes the effect of various types of vegetation and soils on erosion, the nature of erosional resistance of various species and the relation between vegetation types and such soil conditions as acidity, alkalinity, structure, humus content, water content, salt content, etc. Fundamentally erosion control is dependent on vegetation in relation to soil type and topography. The influence of animals in the maintenance of porosity and productivity of soils has been greatly neglected. Seemingly the most favorable conditions for resistance to erosion have developed in native grassland which must be investigated in order to determine the factors controlling erosion and like destructive processes. Rodents are generally considered wholly bad. Only now are investigations being conducted with respect to their possible values in soil aeration and soil building, as a basic food for fur animals and as "safety factors" for game and live stock, and even as active agents (the beaver, for example) in erosion control.

(4) *Basic soil studies.* An understanding of soils, soil types and soil profiles as progressively modified by cultivation and other modes of utilization, and in respect to their organic reactions, can not be gained without continued comparative study of the soil and soil fauna normally present in undisturbed native grassland areas.

(5) *Study of the relation of vegetation and animal life to climatic conditions.* The native grassland must, therefore, be the basis of the study of the influences of precipitation, temperature, humidity, wind and light on plant and animal growth, behavior, distribution and populations. The normal grassland biotic community is the result of the attainment through a long period of development of a condition of equilibrium between the

DUE TO OVERGRAZING, SAGEBRUSH (ARTEMISIA TRIDENTATA) HAS INVADED MUCH OF THE WESTERN EDGE OF THE GRASSLAND, GREATLY REDUCING THE GRASSES, WHICH HOWEVER QUICKLY RETURN IF SEED PLANTS ARE AT HAND AND THE SAGE IS REMOVED. A. A COLORADO AREA IMMEDIATELY AFTER BURNING THE SAGE. SAGE BURNS READILY IN AUTUMN. THE MAN AT THE EDGE OF UNTOUCHED SAGEBRUSH MARKS THE POINT SHOWN IN FIGURES B AND C. B. SAME AS A, ONE YEAR AFTER REMOVAL OF THE SAGEBRUSH. C. SAME AS A AND B, TWO YEARS AFTER REMOVAL OF SAGEBRUSH. RODENT AND CATTLE EXCLOSURE LEFT; CATTLE EXCLOSURE RIGHT; LARAMIE RIVER VALLEY, NORTHERN COLORADO.

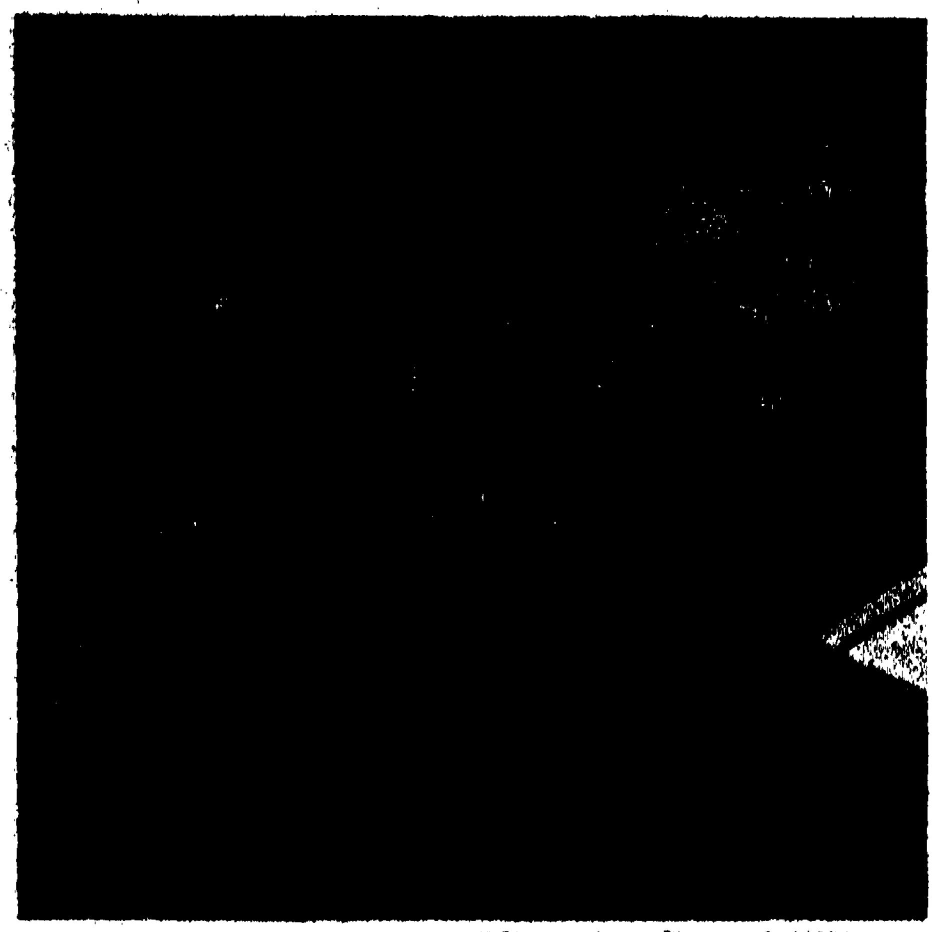


Photo by C. E. Williams

GRASSLAND BIRDS ARE FULLY EXPOSED TO THE SUN

A KILLDEER'S NEST IN THE WICHITA MOUNTAIN WILDLIFE REFUGE.

community and the climate in which it exists. The causes of annual variation in yield and nutritive value of forage and valuable game and other animal life can be determined. The variation and the causes of the beginning and ending of the growth period of most important plant species need determination. This information is of utmost scientific and practical value.

(6) *Study of the relation of animals to climatic conditions.* The data obtained from the studies mentioned in the previous section can be applied also to the study of variability in animal population from year to year. Fluctuations in abundance of animals are of great importance in the development of vegetation, and the converse effect of yearly variation in vegetation upon animal populations can not be overestimated. As stated above, the fluctuations in abundance of game animals are largely unexplained. There is a possibility that some of these effects may be due to variations in vitamin or mineral content of plant food. Such relationships require a great deal of investigation. In order to obtain results, records of fluctuations must be made over long periods of time and coupled with chemical and other related studies. The causes of fluctuations in numbers of insect pests on cultivated crops can not be determined without comparable data obtained from undisturbed grassland.

(7) *Study of interrelations between vegetation and grazing by live stock and by wild animals.* Thorough exploration under controlled conditions is needed in regard to range readiness, deferred grazing, rotation grazing, degree of utilization, frequency of grazing, determination by delicate indicators of over-grazing and palatability studies. Little of the present grazing literature on these subjects is based upon adequate research, largely because of the difficulties in securing sufficient areas of land and in providing for long-continued investigation, but also because of the absence of adequate checks on modifications of natural grassland communities.

(8) *Study of the interrelations of vegetation and biotic factors.* Under certain conditions rodents, which are often indiscriminately exterminated, may be more helpful than injurious because of their largely beneficial influence on the soil, their serving as food supply for valuable fur-bearers and their insectivorous habits. Evidence is accumulating that certain rodents increase in numbers under overgrazing. Similar relationships have been determined for certain species of grasshoppers, which are able to injure vegetation only under conditions of overgrazing. Little detailed work has, however, been done in the determination of such relationships and a great deal of information of value in the control of the animal components of the grassland communities may be gained. The possibility of cultured control has hardly been considered. Long-continued investigation on adequate experimental areas of native grassland is essential.

(9) *Studies of insects and the control of injurious species.* In grassland regions, most insect pests such as grasshoppers are native species, and measures for their efficient control must be based

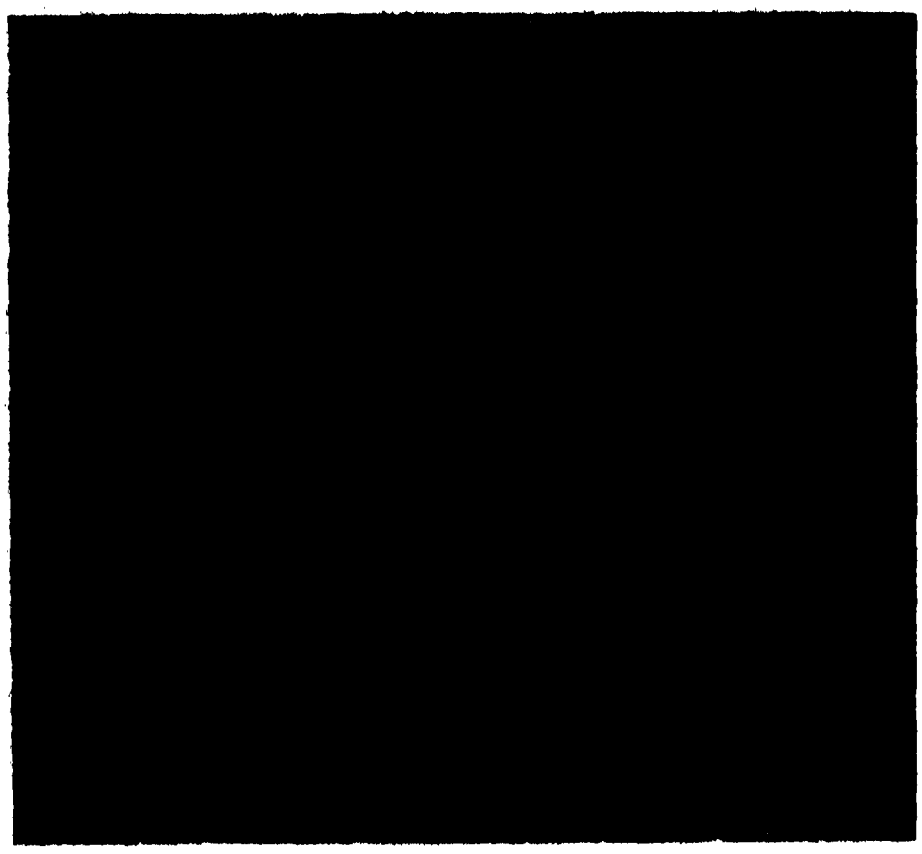


Photo by H. Theo. Hanson

CONCRETE EVIDENCE OF GRASSHOPPER ABUNDANCE

ACCUMULATIONS OF GRASSHOPPER PELLETS IN OLD RUT ALONG ROAD WASHED DOWN FROM HILLS BY RECENT LIGHT RAIN—ACCUMULATION ABOUT THREE INCHES DEEP. A FEW YEARS AGO IT WAS BELIEVED THERE NEVER WOULD BE ANOTHER GRASSHOPPER SCOURGE IN THE NORTH AMERICAN GRASSLAND. WESTERN NORTH DAKOTA.

Photo by F. A. Morton,
U. S. Bureau of Entomology

GRASSHOPPERS TAKE FORAGE

GRASS QUADRAT PROTECTED FROM GRASSHOPPERS. BAXTER RANCH, HARLOWTON, MONTANA.

upon exact knowledge of interrelationships, behavior, life history and protection in the natural environment. In this case also control by cultural methods versus chemical means promises possibilities of large savings and more effective results.

The above-mentioned studies, in order of their apparent importance and feasibility, the committee would inaugurate, as means permit, in Saskatchewan, North Dakota, Nebraska, Illinois, Iowa, Oklahoma, Arizona and Texas under the direction of the biological departments at the universities of these respective states.

The nature of the general problem of administration, in the minds of the committee, is such as to render it much more likely of solution under an endowment administered by a single coordinating board acting in cooperation with the governing boards of the several institutions than it could possibly be if these several institutional boards attempted to set to work without such a coordinating body. It is hoped that the great merit of the problem will be sufficiently apparent to constrain the endowment necessary to materialize the idea into an effective working system.

It is realized that so extensive a program, applicable to grasslands of diverse types, may not be possible of immediate realization. The committee has therefore given consideration to a simpler plan contemplating the initial establishment of a single centralized study center, probably in western Nebraska or South Dakota, where there is hope of cooperation with the federal government.

Another serious need is primarily educational. Unlike many of the universities in the forested sections of North America, which have tracts of forest land available for research conducted by the faculty and for training of research workers and teachers of forestry and land use, the universities of the grassland states now have no equivalent facilities. The extensive grassland studies of the University of Nebraska and the noteworthy work in other midwestern universities have been conducted on leased lands. Unfortunately, the breaking up of such lands by the plow has often interrupted actual studies and made long-time observation impossible. The acquirement of lands close to these educational centers is greatly to be desired.

THE MOUNT EVANS LABORATORY

By Professor J. C. STEARNS
UNIVERSITY OF DENVER

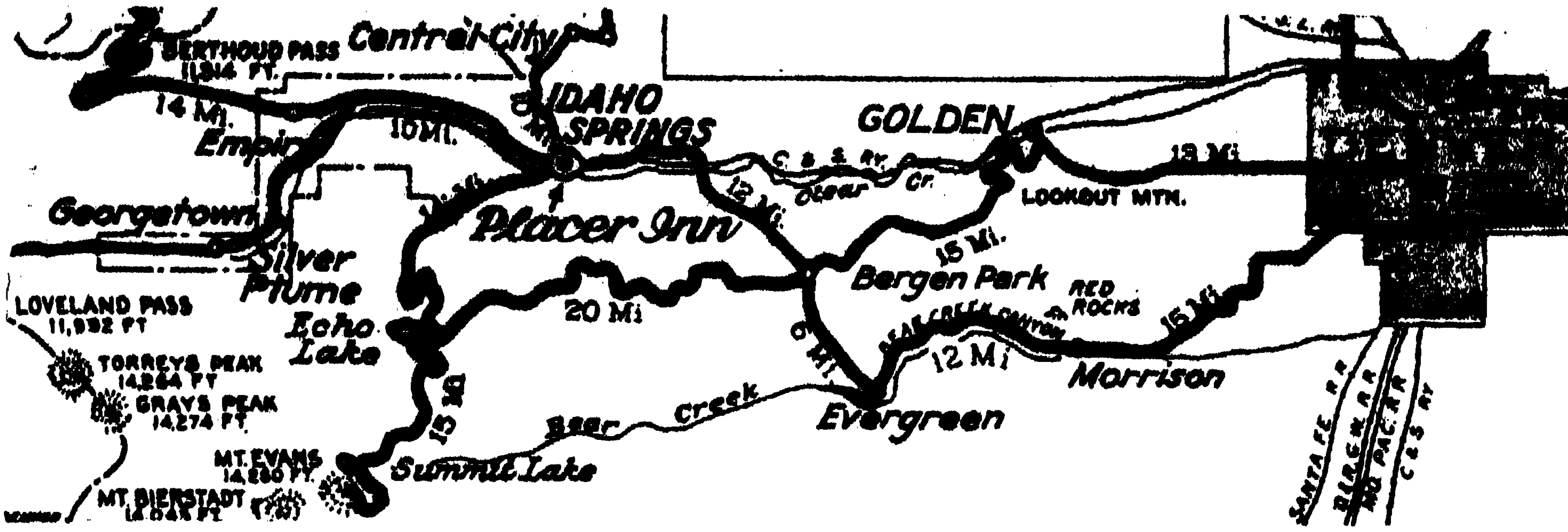
THE construction of Mount Evans Laboratory was begun in May, 1936, and the laboratory was first used for scientific work on June 28, 1937. For those whom this laboratory may serve, the following description of the location, climate, physical plant and policy of operation of the laboratory, as well as the events leading to its establishment, will be of interest.

In September, 1931, A. H. Compton did his first field work in cosmic rays at Summit Lake, which is 1,000 feet below the peak on Mt. Evans. Cosmic ray intensity measurements were made on Mt. Evans for a brief period at this time. The apparatus used was constructed at the University of Chicago and transported to Colorado in an enclosed bus, which served as a cosmic ray laboratory for this first work. The rigors of the climate were such that, with the lack of adequate protection, a trick on the night shift was equivalent to a polar expedition. This expedition was followed by others headed by R. D. Bennett, Massachusetts Institute of Technology; T. H. Johnson, Bartol Research Foundation; J. C. Street, Harvard; D. K. Froman, McDonald College of McGill University; and J. C. Stearns, of the University of Denver.

These early workers and their associates used tents for laboratories and living quarters. The wind velocity at night was often sufficient to level tents and scatter equipment. The fire hazard prevented safe heating of tents, and the indoor temperatures often fell to 30 degrees F. or lower. Both apparatus and workers were without protection from the frequent electric storms.

The intensity of cosmic rays at the alti-

ECHO LAKE LODGE
FIFTEEN MILES FROM THE MT. EVANS LABORATORY.



MAP SHOWING LOCATION OF MT. EVANS
SUMMIT LAKE, ECHO LAKE AND IDAHO SPRINGS.

tude of Mt. Evans (14,260 feet) is five times that at sea level, offering an opportunity for a corresponding increase in the rate of collection of data in some aspects of the studies. However, it was evident that if any prolonged or accurate observations were to be made, some sort of adequate shelter must be provided for workers and apparatus. Dr. K. T. Compton, president of the Massachusetts Institute of Technology, and Mr. John Evans, an alumnus of the Massachusetts Institute of Technology and chairman of the board of trustees of the University of Denver, investigated the possibility of erecting a suitable building for this purpose. The result was a project sponsored jointly by the Massachusetts Institute of Technology and the University of Denver.

Location

The following considerations led to the selection of Mt. Evans as the site for the

TIMBERLINE TREES
NEAR THE MT. EVANS HIGHWAY, ABOUT TEN MILES FROM THE LABORATORY.

LABORATORY AS SEEN FROM THE TERMINUS OF THE AUTOMOBILE ROAD

laboratory: (1) It is the highest easily accessible mountain peak in the United States. (2) There are living accommodations on the Mt. Evans highway at altitudes of 10,600, 8,000 and 6,000 feet, respectively. (3) Mt. Evans is located near a city where scientific apparatus and supplies may be secured. (4) It is located near two universities, whose staff members are engaged in experimental work in cosmic rays.

Mt. Evans is 65 miles from Denver, at the terminus of the highest automobile road in the United States. The altitude of the peak, 14,260 feet, and about 2,500 feet above timber line, affords a clear horizon in all directions. The nearest available hotel is Echo Lake Lodge, at a distance of 15 miles by road and at an elevation of 10,600 feet. Idaho Springs is the nearest source of supplies and is 29 miles by road from the laboratory.

Climate

The barometric pressure averages about 45 cms. and the temperature during the summer months varies from 15 degrees to 70 degrees F. Though the wind velocity is sometimes excessively high and there are frequent afternoon sleet and snow storms, the mornings are often calm and clear. At times the electric poten-

TRAILING THE INVISIBLE

GROUP OF PHYSICISTS ATOP MOUNT EVANS, THREE MILES ABOVE THE SEA, MEASURING COSMIC RAYS. FROM LEFT TO RIGHT: WILCOX OVERBECK, UNIVERSITY OF DENVER; DR. J. L. DUNHAM, OF HARVARD UNIVERSITY; DR. RALPH D. BENNETT, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DR. ERVIN H. BRAMHALL, OF CAMBRIDGE UNIVERSITY, ENGLAND; DR. JOYCE C. STEARNS, OF THE UNIVERSITY OF DENVER.

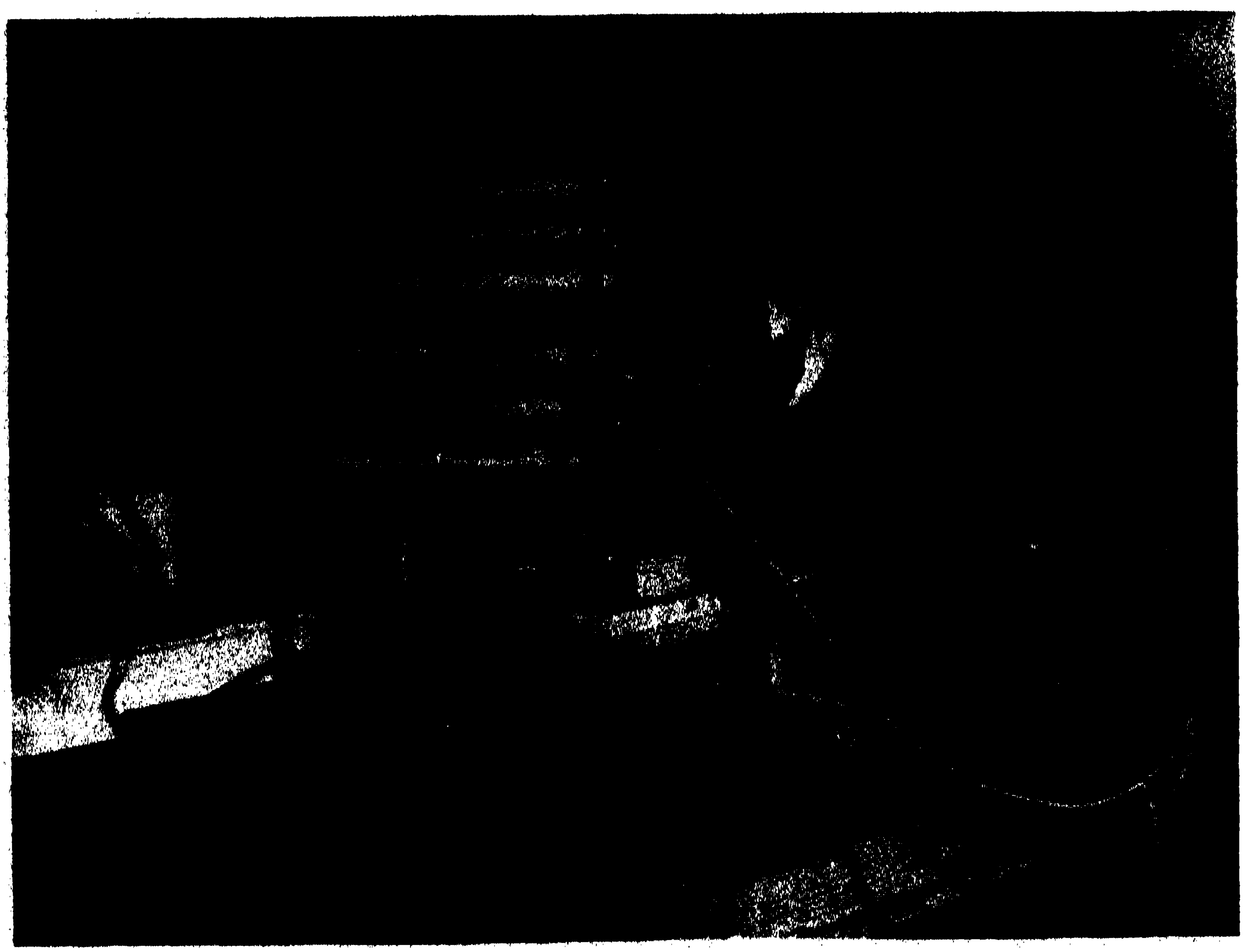
tial gradient is high enough to produce marked corona discharges from rocks and other projections, including persons. The weather is usually milder in August and September than in July. There is seldom a day which does not present a sample of all the seasons except midsummer at the lower altitudes.

The Physical Plant

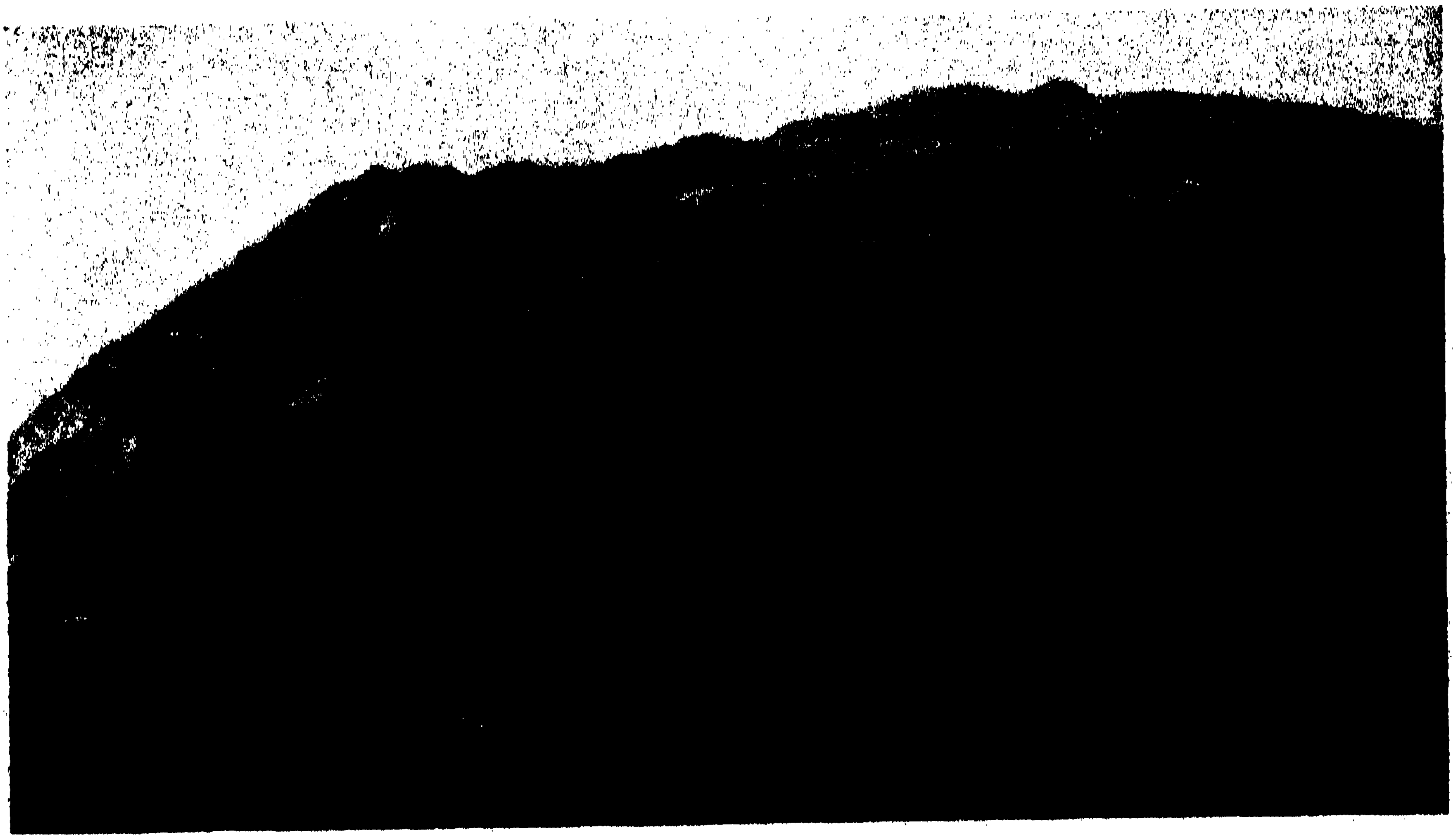
The laboratory consists of two rooms, each having a floor space 21 by 24 feet, with a height of 11 feet at the center, one room being used as a laboratory and the other for living quarters. Six permanent cots and mattresses of the submarine type are provided, and additional folding cots are available should they be required. There are also tables, chairs, stoves and other necessary household equipment. A 500-watt, 60-cycle, 110-volt, gas-engine driven generator is housed in the laboratory.

To withstand the high wind velocity, a roof truss construction was employed, which made the omission of side walls possible. Cables fastened to the floor joists run through the pillars of the foundation to heavy metal plates cemented into the rock. The building is thermally insulated and is easily heated. Louvres provide "no draft" ventilation.

For protection against lightning, the end walls and roof are covered with thin copper shingles, and the lower side of the floor is covered with metal hardware cloth. The copper and hardware cloth are joined and earthed, thus converting the whole building into a Faraday cage. The copper of the roof is not thick enough



GEIGER COUNTER TELESCOPE
USED IN MT. EVANS LABORATORY, SUMMER, 1937.



ROAD LEADING TO MT. EVANS LABORATORY
WHICH IS 200 YARDS FROM THE TERMINUS.

to materially interfere with cosmic ray measurements.

Many people and government agencies cooperated in the constructing of this laboratory. Mr. Burnham Hoyt, the architect, was responsible for the unique plan. The building was pre-fabricated in Denver, sawed into sections, and then transported to Mt. Evans by a caravan of trucks furnished by the City of Denver. George E. Cranmer, superintendent of Denver Mountain Parks, helped to secure this excellent assistance. The sections were carried from the terminus of the automobile road to the building site on the peak by CCC labor, assigned to the Forest Service of this region. Permission to erect the laboratory at this location was granted by the Forest Service of the United States Department of Agriculture. Colonel Allen S. Peck, of the U. S. Forest Service, cooperated fully in securing this invaluable aid from the United States government. Mr. T. F. McKay, the builder, worked under severe weather handicaps and without profit to produce the excellent structure.

Experimental Work, Summer, 1937

The following projects were carried out during the initial year of the laboratory: Professor Victor Jollos, of the University of Wisconsin, investigated the possible mutations produced in Drosophila by cosmic primary and shower radiation; Professor Fred D'Amour, of the University of Denver, studied the effect of shower radiation, produced in lead, on the reproductive processes in rats; Professor D. K. Froman, of McGill University, and Professor J. C. Stearns, of the University of Denver, studied the variations in cosmic ray showers produced in different metals, and the effects produced by different thicknesses of the same metal. It is interesting to note that while these biological and physical investigations originated independently, the work became a cooperative one to the extent that the adequate interpretation of biological effects required the data which were obtained in the physical experiment.

Professor T. R. Wilkins, of the University of Rochester, continued his inter-

SHELTER HOUSE AT SUMMIT LAKE. MT. EVANS IN THE BACKGROUND
SEVERAL EXPEDITIONS UTILIZED THIS FOR EARLY MEASUREMENTS ON COSMIC RAYS.

esting work on particle tracks in photographic emulsions which was begun before the laboratory was completed. Emulsions which permanently record the tracks of ionizing particles were exposed for six weeks in the laboratory.

Purpose and Availability

Though the beginning is a very modest one, it is hoped that this laboratory may grow to serve the United States as well as the Jungfrau laboratory serves Europe. To that end the physical plant will be enlarged and improved as the demand warrants. With this in view, Mr. Burnham Hoyt has prepared very interesting plans for a more adequate laboratory if and when there are indications that a demand for such additional facilities exists. The present laboratory is available at the small cost of operating expenses to qualified workers in physics, meteorology, astrophysics, biology and other sciences who wish to carry on experiments at this altitude.

For the 1938 season, if snow conditions are normal, the road to the laboratory will open about June 25, and remain so until late September. The laboratory may be reached at all times of the year on snowshoes over the fifteen miles from Echo Lake, the limit to which the road is cleared in winter. Those contemplating working at the laboratory should make arrangements well in advance with Professor J. C. Stearns, of the University of Denver.

MAN'S ANCESTRAL HOME

By Dr. HERVEY W. SHIMER

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WHAT is the region and what the environment in which man became differentiated from other animals and became *man*? In other words, what is his ancestral home?

In searching for the answer to this question, we are led to the consideration of when the human stock arose, and from what remote ancestor. It is generally held to-day that man and the living anthropoid apes are very closely akin, and that they have probably arisen from a common ancestral stock. Every bone of the skeleton of man, nearly all his muscles, nerves and blood vessels, the arrangement of the viscera, the placenta, and many other characters, are fundamentally identical with those of the living anthropoid apes.

Human ontogeny, moreover, indicates such relationship. During the early foetal stage (fifth to sixth week of embryonic life) the bodily proportions of man and the higher apes are very similar. From this time to maturity they diverge. In the early foetal stage of both groups, the arms are much longer than the legs; in the adult apes this condition in general is retained, while in man the legs lengthen greatly in proportion to the arms. The human nose becomes higher and narrower from the early foetus to the adult; in the adult ape it remains near the foetal condition. From a similar condition of thumb and hand, the apes have developed the hand into a hook-like grasping organ, with a degeneration of the thumb, while man has retained the broad hand and has developed the thumb into a tool-making instrument.

It is thus seen that while man and the living anthropoid apes have probably descended from some common ancestor, man could not have evolved from any of the living apes. Each line has become too specialized. In the narrow hand with hook-like fingers and reduced thumb, apes have passed beyond the more generalized hand which they possess during their embryonic development and which man carries on into adult growth. It is, accordingly, not in the habitat which apes find congenial that we should look for the environment which would promote the evolution of early man.

How long ago did this divergence take place? The divergence of a common ancestral stock into anthropoid apes and man must have begun at a time sufficiently remote to permit of the vast changes which now distinguish the adults of the two groups. The few thousand years of historic time have witnessed slight changes in man's body. Even the human being of mid-glacial times, 500,000 years ago, differed not very greatly from modern man, mainly in skull and lower jaw and less erect posture. Man of even early Glacial time, a million years ago, had diverged vastly from the ancestral anthropoid stock, as indicated in the ontogeny of both man and apes—a divergence seen in the relative length of arms and legs, the shape and size of hands, fingers, feet and toes, the change in height of forehead, length of face, length of nose, the uprightness of the body, the curvature of the backbone. This great length of time since our common ancestor lived his life in the environment we are trying to picture is indicated likewise in the changes that living anthropoid apes have developed from the ancestral stock.

The extinct anthropoid ape that most satisfactorily combines the characters of apes and man which we consider this common ancestor to have possessed is Dryopithecus. He was a tree-dwelling anthropoid, as large as a chimpanzee. The canine teeth forecast the human in their relatively small size, not fang-like as in the adult modern ape, but more like the teeth of the young ape or of adult man. This genus is known from the Miocene and Pliocene of Europe and Asia. Some species are closer to man and some are closer to the chimpanzee and the gorilla. The molar teeth, which are so often the paleontologist's chief dependence in tracing relationships among the vertebrates, show certain arrangements of cusps and grooves on their grinding surface. The pattern of these in Dryopithecus is least modified in the Upper Pliocene man of Piltdown. It is retained in the youths of the later Pleistocene races but becomes obscured in maturity. The living adult apes, on the other hand, have retained the pattern with divers slight modifications, while adult modern man has departed from it most widely.

From these and other considerations, it seems that Dryopithecus, most closely of all fossil apes so far found, embodies our ideas of the remote common ancestor of both apes and man, which means that it is back to some region as it was during the Miocene, some twenty million years ago, that we look for man's ancestral home.

Our search is conditioned by the sort of environment which as a stimulus acting on innate organic changes, would initiate, or at least promote, the divergence between apes and man. Constant though slow variation is characteristic of all life. In certain groups, however, change is more rapid than in others. Whatever the causes of these changes, whether internal or external, there is little doubt that the environment acts as a pruning knife, cutting off those individuals and species least adapted to it.

If man is descended from the tree-dwelling Dryopithecoid or nearly related stock of large anthropoids, the problem is, what sort of environment would promote the divergence of this stock into the present tree-dwelling apes and ground-dwelling man. A very strong impetus and a most efficient selective factor must have operated to force the man line out of the comparative safety of the trees to the untried vicissitudes of life on the open ground. Even to-day man does not change his habits except under compulsion. The only cause which investigators at present consider of sufficient force to have brought about this change in habit is the slow, gradual transformation of the large wide-spreading forests of a humid region into the almost treeless condition of a semi-arid region. The individuals which could survive under such slowly changing climatic conditions would be those which developed in the direction of becoming ground runners, first to go from grove to grove, and as a next step, to use the trees only as places of refuge.

A tendency to increase in size is manifested in most families of animals. The lines of the horse, camel, rhinoceros and elephant began with very small animals. Man's own line, the Primates, began with animals about the size of small rats, and has reached to-day the size of ground-dwelling man and the semi-arboreal gorilla. A sufficient increase in size, however, to leave man less at the mercy of enemies on the ground would, on the other hand, prevent him from leaping freely through the trees. Hence he would need to live to an increasing extent upon the ground.

The great development of the forebrain in the early anthropoids had forced upon them a semi-erect attitude for forward looking. Hence in living upon the ground they would become more and

more erect. Long legs are an advantage to a running animal, as is seen in the evolution of the horse, the deer and the ostrich. Animals which developed longer legs, other things being equal, would survive longer and thus have a greater number of offspring. Hence in succeeding generations of human beings life on the ground would promote an increase in the proportional length of the legs. That the ancestors of present-day man developed running ability rather late in the geologic time is shown by the fact that in man the increased length of leg over arm takes place after birth, for at the age of a month the human baby has leg and arm of equal length.

In the foot, too, though dissection of the muscles shows that the foot of chimpanzee and gorilla is operated by muscles which correspond to those in the human foot, yet the human foot has been modified by long ages of running on the ground, so the great toe is longer, the outer four toes have become shorter, and all are drawn inwards towards a median line. A tendency towards increased length of one or two toes and the reduction of the others is seen in all running animals; note the ostrich, horse and deer. The anthropoids, which continued living in trees, on the other hand, have retained the spreading toes, with the great toe projecting like a thumb.

Life upon the ground, with an increasing uprightness of body, would induce a change in the profile of the backbone, and likewise tend to develop a more flexible and opposable thumb. For the hand, freed from use in walking, could be utilized in lifting objects up to the face and turning them about for examination. Those individuals in which the cerebrum was enlarging most rapidly could take most advantage of such examinations and be most prepared to survive in this new habitat on the ground, this habitat that would demand quick thought and rapid decision.

Just as it has been shown that a region undergoing increasing aridity was the theater for the evolution of such a cursorial animal as the horse, so this running ability of man points to a region of increasing aridity as the probable theater for early human experiments. What of the region and time of this change from ancestral anthropoid to man? Where was man's ancestral home?

We naturally look for an answer to three lines of evidence. First upon what continents and during what geologic times did the ancestral stock live? Second, where have the earliest remains of man been found? Third, where, upon these continents and at the requisite time in earth history, is there evidence of a change from a forested to an almost treeless condition, and in a region sufficiently extended to provide space for all the interactions taking part in such an evolution?

First, as to where and when man's ancestors lived—or rather those lines that are supposed to have been ancestors. *Dryopithecus,* belonging to such an ancestral stock, or at least representing a close relationship, has been found only in the Miocene and Pliocene of Europe and Asia. The fossil skull from South Africa, known as the Taungs infant, is also pertinent to this query. This skull has some characters which relate it to man, but more relating it to the chimpanzee-gorilla line. It is difficult to evaluate the skull of an infant in terms of an adult, since an infant possesses ancestral characters which it loses during its growth to maturity. This skull, however, points towards a common ancestor of apes and man. Its age, as given by Broom, who described the associated fauna, is Lower Pliocene, though Dart and Keith consider it as Miocene.

Thus fossil evidence of the common ancestor of man and the apes has been found in Europe, Asia and Africa, and lived during the Miocene and Pliocene.

As to our second query, the earliest remains of man himself have so far been found only in Europe and Asia. These oldest skeletal remains are: *Eoanthropus* (the Piltdown man) from the late Pliocene or earliest Pleistocene of southeastern England; *Sinanthropus* (Pekin man) from early Pleistocene near Peiping, China; *Pithecanthropus* (Trinil man) from the early Pleistocene of Java, and *Paleanthropus* (Heidelberg man) from the mid Pleistocene of southwest Germany. These four extinct genera of primitive man occur on the periphery of the Euro-Asiatic land mass.

Now Matthew has shown that the most primitive members of a group of animals are those that are found farthest removed from the center of the evolution of that group. For a center of dispersal is the place where evolution is at a maximum. Those individuals that can not compete here are forced away from the optimum habitat and try to adapt themselves to less than optimum conditions. If this original center became, for example, too arid for an optimum habitat, other centers of dispersal would develop in other regions of more favorable climate and food supply for that particular group of animals in their particular stage of evolution. Applying Matthew's generalization to the dispersal center of earliest known man would place it somewhere in central Asia.

North and South America may be omitted from our consideration, since no fossil anthropoids have been found on either continent and their more distant relatives, the New World monkeys, that are found here, are built on a different plan, which shows that they are an earlier offshoot from the Primate stem. All fossil human remains that have been found in the Americas belong to the stage of living man, *Homo sapiens*.

The ontogeny of man, that is, his growth from the foetal stage to adulthood, indicates an ancestral change from an arboreal habitat to life on the ground. So our third line of inquiry is concerned with the search for a locality where man would receive the stimulus to change from an arboreal to a ground habitat. Probably the only compulsion of sufficient strength to bring this about would be a change in climate from humid to semi-arid. And such a change would probably have been due to the rise of a mountain chain across the course of the moisture-bearing winds. What regions in the Old World fit such an hypothesis of changing climatic conditions in mid to later Tertiary times?

Europe may be rejected as a possibility. This continent receives its principal rain supply from the Atlantic Ocean, and since no mountain chain extending in a north-south direction was upheaved in western Europe during mid or late Tertiary, its climate has remained rather stable.

In Africa the problem is more complicated. There are no mountain chains of mid Tertiary or later origin to cut off moisture-bearing winds, but during the later Tertiary the continent was elevated, and this tended to reduce the number of trees in certain inland areas. At present, however, it seems doubtful if there is sufficient evidence to include any part of Africa among the candidates for man's ancestral home.

It is in Asia that we find most fully exemplified the required climatic conditions occurring at the right geologic time to fit the fossil evidence. At the close of the Oligocene the Himalayan mountains had their first period of folding and elevation. The Siwalik geosyncline, formed at their southern margin and filled with Miocene and Pliocene sediments, gives evidence, in the uniformly coarse sediment from bottom to top, of the continued rise of the Himalayas during this time. After the Pliocene these Siwalik sedi-

ments, 16,000 feet thick, were folded, forming the Salt Range, accompanied by a further elevation of the Himalayas and the formation of the Indo-Gangetic geosyncline along their southern margin.

It is thus seen that the Himalayan ranges, beginning to rise at the close of the Oligocene, continued to be uplifted at intervals during the Miocene and Pliocene and Pleistocene times. The rising of these east-west trending mountains tended to shut out more and more completely from their northern side the monsoon rains from the south, practically the only source of moisture in this region.

During the Oligocene, the Tibetan and adjoining regions to the east and west, and north probably to parallel 50°, were apparently low lying, well watered and heavily forested. Coal beds of this age in Manchuria contain such deciduous trees as Populus, Carpinus, Alnus, Dryophyllum and Fagus, and such conifers as Sequoia and Glyptostrobus. These forests probably covered all central Asia, with the incoming of some warmer temperate trees in southern areas, such as Tibet; but no plant fossils have as yet been found in the southern part of this area. The region was apparently well drained; that it was forested is shown by the presence of such mammals as the colossal rhinoceros *Baluchitherium,* as large as an elephant. This animal could not have crossed deserts or high mountains, yet its remains are found from Baluchistan through Russian Turkestan, Mongolia and Ordos in central China.

We find here, then, in southern Asia all the postulated requisite conditions for the evolution of man from a generalized anthropoid of a type very similar to *Dryopithecus.* Moreover, this genus has been found in this area in the Siwalik sediment of Miocene age.

If southern Asia was man's ancestral home, we may conceive members of the Dryopithecoid or nearly related stock as occupying the region from southern India north to beyond Tibet. From this territory they probably migrated to some extent north or south with the seasons, thus facilitating mixture between the more virile temperate tribes and the less progressive tropical tribes.

Man, like any other animal, develops most rapidly where he must use all his faculties, physical and mental, to survive. If the temperature is so low or the food so limited in quantity and variety that the physical body must use all its energy to maintain itself, no energy remains for mental development. When, on the other hand, the temperature is high and the food plentiful, there is only slight compulsion for either physical or mental activity. Hence it is to a temperate climate that we must look for the scene of man's evolution.

We may, then, postulate man in his ancestral home at the close of the Oligocene some twenty to thirty million years ago, unconsciously affected by the beginning of the elevation of the Himalayas. The winds from the Indian Ocean, bearing moisture to the forests of his homeland, were, during the successive ages, increasingly intercepted by this rising land mass, and less and less of the moisture reached the northern slopes. The water table consequently sank and the forests slowly disappeared.

During this long time many changes would be taking place in the ancestral anthropoid stock; for the Primate order, to which man belongs, is like the ungulate and carnivore orders in being subject to rapid evolution throughout Cenozoic time. Those individuals which developed characters which were advantageous in a region of decreasing forest cover and numerous ground-living enemies would survive more frequently than those less favored. That is, as the formerly continuous forested areas became divided into separate groves, these anthropoid

ancestors of man, caught to the north of the mountain barrier, would be forced to run from one grove to another in the search for food, and thus be forced out of the comparative safety of the trees. As the groves became smaller and more distant from each other a rapid elimination of the slower-witted and less agile members must have taken place. Those with longer legs and larger brains would survive most frequently. The curve of evolution would, accordingly, be in the direction of brain and speed.

In our search for man's ancestral home, we are left with much uncertainty and many unanswered questions. The strata of south central Asia are a vast and largely unexplored treasure chest. It may well be that from them future investigators may learn if it was assuredly there that the human stock arose, and, if so, in what environment of plants and animals the first men lived their lives.

And so as we look back down this tremendously long and poorly lighted avenue of years, it must be largely with the eyes of the imagination that we see this half-human ancestor of ours. Instincts and vague gropings and hungers from within, meeting the menaces and challenges of the environment without, would keep the slow brain active. The search for food and the avoidance of carnivorous enemies would put an increasingly valuable premium on larger brains, longer legs and better hands. Safety depended on being an animated question mark. Since asking questions is still a human characteristic, it is still as a question that I leave this subject of man's early home.

EXPLORING A REALLY "NEW" WORLD

By ERNEST INGERSOLL

NEW YORK, N. Y.

THIS essay seeks to show how America first became explored and gradually occupied by immigrants from Asia, who came across Bering Sea and then spread southward; it is based on undisputed facts, reviewed in the light of imagination. Initially, however, boats similar to those made by modern Eskimos (frames of wood or whalebone covered with sewn skins of walrus or seal) brought the earliest comers to the shores of this continent and were used as long as men remained within the Arctic Circle, where alone the hides of those animals were obtainable. Southward of that region, the only boat possible to the means and ability of these visitors was one shaped of wood. Unless they could provide themselves with this means of transportation as they moved along, the primary exploration and possession of a totally unknown and vacant continent, furrowed by rivers, was virtually impossible; inasmuch as the amazing project of these immigrants was accomplished by its aid, the wooden canoe has become enshrined in the history of human life on this continent. Therefore, it is worth a moment's attention.

The earliest human beings imaginable must have been associated with rivers and other bodies of water, and have ventured to enter them and make more or less voluntary efforts to swim. When imperiled by sudden floods or other mishaps they would try to save themselves by seizing drifting logs or lesser bits of wood. Animals constantly do so. A youth might thus mount a floating log and, by paddling with hands and feet, manage to guide it; but round logs are tricky, while flat pieces are safer. When these proto-humans had acquired the means of doing this they would next trim and flatten a chosen log, at least on top, and so be able not only to sit on it securely, and move it as they pleased by means of a pole or a leafy branch or a piece of bark, but also could carry something with them. Such a deck-load would be less likely to fall off were the top of the log somewhat hollowed; this done, the first step has been taken toward the one-piece canoe, naturally named a "dugout."

A dugout, then, is a sound tree trunk or log hollowed into a trough and otherwise shaped into usefulness as a boat. The form may vary as the purpose, materials and adaptive skill of makers differ, but the *type* is fixed, all over the world, by the very nature of its structure and conditions and character of usefulness. Undoubtedly it, or at least the art and method of making it, was brought by the first human persons to set foot on this continent—men who came across the Bering Sea from the northeastern extremity of Siberia. Indexed by its highest examples in workmanship and in fitness for local requirements, *the dugout may be considered the one perfected product of human thought as an instrument of service.*

This momentous event may be roughly placed at twelve thousand years ago. At that time the stupendous glaciation which had buried much of the northern hemisphere had melted sufficiently to release eastern Siberia, and also the western half of the area of the United States of America, from its deadly grasp. Thanks to the warming influence of the Japanese current probably both shores of the North Pacific were soonest freed of ice—at any rate, vegetation and animal life could

occupy them. Long before that time southern and eastern Asia appears to have become populated; gradually southern Siberia was overspread by humanity; and at last men had spread, perhaps by force rather than device, even to the cold and desolate seashore of Kamchatka where they were compelled to subsist almost wholly on fish and marine animals and birds. Pushing, or pushed, on northward they finally reached the Arctic coast and wandered out upon East Cape, from whose hills distant land could be seen beyond the icy or tempestuous waters of what we now call Bering Strait.

No place as a home could be worse than where these forlorn men and women were; was it not possible, they must have asked each other, that the mistily notched horizon, possibly islands, held better conditions for human existence? One may feel certain that soon certain energetic souls among these brown-skinned Mongolians—if so they were (?)—led by curiosity and hope, crossed the strait in skin boats, or by foot on winter ice, and landed where there were plains like those they had left—or better. Returning, they told of herds of seals and walruses easily accessible, of game plentiful and incredibly tame, of marvelous flocks of birds and annual supplies of eggs inexhaustible; of new and plentiful fishes and whales. Other scouts followed, went farther and farther southward along the coast, and came back with a report that made previous advantages seem small—rivers crowded with *salmon!* That, more than anything else, established the attractiveness of the new land. Well did the Siberians know this precious food-fish, and the knowledge that it abounded there encouraged the most timid to seek a home on the opposite shore, so that in a relatively short time a colony or village—men, women, dogs and gear—was established on the blank beaches of Alaska.

Such was the planting of the seed that was to populate the New World and bring into existence a new class of mankind—the American Indians.

These ancestral immigrants, although perhaps as poor specimens of Asiatics as could be found, were not wild savages, "cave men" of the Paleolithic Age. They were well in advance of it, for they had attained to some skill with tools, an acquaintance with certain domestic animals and the rudiments of agriculture, and their descendants never rose much higher until Europeans supplied them with, and taught them the uses of, iron and horses. Theretofore articles and implements of stone and bone, sea-shells, wood and leather fulfilled the mechanical requirements of their simple lives.

Awakened by what in their boldness had already been accomplished, these hardy exiles set themselves to learn what remained of possible betterment. The almost barren *tundra* furnished them some food and caribou and bird skins for clothing, but otherwise held neither attraction nor promise. Hopefully exploration continued southward, afoot and by boat and dog-sledge. The ever-searching scouts reported little either helpful or harmful, and had always to answer "No" to the eager question, "Did you see any men?" Who can estimate how many years or centuries elapsed before discovery was halted by the Yukon River, miles wide so near its mouth? Many generations before this the original landing-place at the tip of Seward Peninsula had been abandoned, and most of the enlarging population had moved southward and now were gathered by the Yukon, and were building huts and fishing-stands. The banks were lined with drifted logs, from which big canoes could be carved, and in them, in the course of time, young men ascended the river until they sighted ranges of dreaded mountains, then turned back to make report and to advise their friends against any movement in that direction. No sight or sound of any human being had disturbed

the solitude of the valley or relieved the voiceless loneliness of the dreary coast. Awe-struck grayheads declared the country must be bewitched; young men and women retorted, "At any rate it is *ours*," and determined to follow the sun toward the south.

Let us suppose these Neoliths stayed near the Yukon until they had doubled or trebled their numbers, yet, if so, a drifting southward must have soon begun. This was inevitable, for food was obtainable there for only a limited congregation of people, and the only path open lay between the mountains and the sea. That moving became a migration, ever pressed forward by its own weight, even though it left behind it a thin string of tiny settlements.

What a progress that was—compulsory, unguided, stumbling, halting, going on none knew whither or why! Did hope revive when they came to the forests of southern Alaska, or were they dismayed by what they had never seen before—masses of trees, amid whose shadows lurked dangers real and imaginary, chilling the heart of the boldest of men. On the other hand, think of the excitement, if not joy, of the succession of new scenes and experiences that were constantly met! No possible information was accessible to them save through their senses. Nobody was here or ever had been to tell them what lay even a day ahead, or leave the slightest record for guidance. Their forefathers had never seen two trees together; and who were these forefathers? They had forgotten hundreds of years before—stories of mythical happenings and hero-tales of mixed men and animals made impossible traditions. Yet we must believe that their minds were awakened anew and grew year by year as they struggled to advance through difficulties, rigors and fears almost inconceivable, as they crept along the hundreds of miles of Alaskan seacoast. Minds were stimulated, bodies strengthened, and only the "fittest" survived; but none could have gotten through had it not been for their dugouts!

At last, no one knows when, these migrants were safely cruising, or pleasantly marching, along the warm "inland passages" beside the British Columbian coast. Even so they found there little change in geography or resources as they advanced, lured by the softening climate and the habit of pressing forward; but hope was fading. Countless generations had lived and died, held as in a vise between an inexorable ocean and impregnable mountains. Would the gods ever free them from this narrow prison? Such an expectation seemed vain.

Then with almost startling suddenness the mountains stepped back, and a wide, beautiful space opened before their weary eyes and feet—the shining expanse and gently sloping shores of Puget Sound. Here was warmth and rest, abundance of food and comfort, every benefit except companionship. No human cry answered their hail, no glare of flame or signal-smoke aroused response, no enemy contested invasion. Here must have slowly accumulated the first considerable stoppage of marching and a gathering of migrant bands; and it is logical to believe that here a village soon arose to become a persistent nursery and a center of distribution of the American race ten thousand years later labeled "Indians." The formidable continental forest grew to the margins of the Sound, firs, cedars and their ilk two or three hundred feet tall rising from a nearly impenetrable undergrowth. A little way beyond, however, was an open, grassy space, the Nisqually Plains, and this may have been the site of the settlement. We may also feel certain that a limited area by the water was gradually cleared by means of fire and stone hatchets, and that from the enormous logs of drifted or fallen trees began to be carved forerunners of those big and graceful dugout-canoes, after-

ward known as "Chinooks," that became the pride of the Northwest.

While this assemblage of lodges and their residents grew in size and importance, continual arrivals of migrants from the north made it, as I have imagined, into a nursery of a new race. This race was still in its Stone-Age childhood, but it had intelligence sufficient for its immediate necessity, and improvable as stimuli appeared. I try not to magnify these Neolithic "children," but their descendants formed the League of the Iroquois, erected the astonishing structures and philosophy of the prehistoric Mexicans and bred the dynasty of the Incas of civilized Peru. Those were the products of self-developed brainwork.

Meanwhile, inspired by the inbred, forward-looking curiosity and spirit of the tribes energetic leaders soon began warily to penetrate and examine the region ahead. Dread of the woods had long ago been overcome. Nevertheless, three age-long mysteries vexed all minds, and kept alive ancient fears and superstitions: First, what lay behind that seemingly endless wall of mountains that hid the sunrise? Second, why were no human inhabitants visible? Third, was this territory an island, or could it be a dreamland, a delusion? The object in the minds of the leaders of the projected resumption of southward exploration was to find answers to one or all of these really vital questions. Pioneers began to hew their way through the untracked forest, and homeseekers slowly followed their trail broad and beaten, with here and there a lodge where a trapper or a family had paused for time. Season after season came and went, and the trail lengthened out, for nothing, not even an ending, seemed to come of it. Then one day a worn man broke out of the woods, and lo! a vast river filled his vision—the Columbia!

It was not merely the amazing breadth of it, the impressive movement seaward of that unruffled volume of water, the startling thought of a bar laid across the path of further search—these were unconsidered flashes across the eyes and mind of the foremost adventurer standing statuesque beside the noble stream. What really stirred his emotion was the thought that here, at last, the mountains stood apart—that here was rent the gigantic screen that for generations had hid from these wanderers whatever of good or bad lay behind it. So vast a watercourse, he reasoned, must have been gathered from wide and distant sources. Evidently a spacious land, not another ocean, confronted him and this flowing river of sweet water was a road by which it might be reached and its riches learned. Let others cross its current and follow the seashore south as far as they pleased, he and his dugout would voyage upward and eastward into a new world.

So it came about. Little by little, more and more, the people followed their daring leaders up the river. Who could count the years of time expended, who can estimate the facts first learned, the experience and knowledge gained, the growth in intellect and skill required to teach those men and women how to avail themselves of novel resources of food and clothing and adequate shelter.

In time the fierce current of the upper river and massive mountains north stopped advance by canoes. Many pleasing valleys had been left untried, but just here opened a most inviting tributary from the east, the beautiful river now called Clark's Fork of the Columbia. Traced to its source it led the migrants, afloat and ashore, through the varied scenery of this northwestern corner of the Union until they found themselves again confronted by mountains—the long, snow-crowned Bitterroot which stood north-and-south squarely across their progress.

What a trek that was! An unseen,

tenantless, seemingly limitless land. No roads, no guide, no help! Always difficulties and dangers just ahead—risks to be repeated again and again, terrors inspired by superstitious fancy and ghostly loneliness. Great cats, bears, wolves, rattlesnakes surround them, freezing cold, blistering heat. Centuries, perhaps, had passed before this stage of the expedition was ended at the foot of the Rocky Mountains, and a wide space of country with its capability for maintaining human life had been tested.

By this time a line of more or less connected villages and hunting camps marked and kept open a line of communication with the Pacific Coast, and constituted a line of retreat. It needed no military guarding against any humanity save marauders of their own kind, and tribal rivalry and quarrels. But none of those in front, at least, were thinking of a retreat. They were studying the problem that vexed their ancestors, of how to get behind this new mountain-wall and spy out what was there. The thousand-year-old question was not yet completely answered, and an unsatisfied curiosity urged further efforts. In response, an expedition bent on more discovery scrambled through Hellgate Canyon, and found beyond it a break in the range that let them through eastward into a maze of heights and depths, broad peaks and narrow gorges—the heart of the Rocky Mountains. Scouting parties began to get glimpses of lofty peaks ahead whence rivers came. Others followed them, joined from time to time by adventurers who, long before, had turned aside from the Columbia column, and had toiled by boat or afoot up the courses of the Snake, the Salmon and the St. Joseph rivers, which had led them to this lofty meeting-place in the midst of the Rockies. At last the leaders, now gray-headed and wise in the craft of mountaineers, gathered together their nearest companions to climb, at what appeared to be a low place, to the crest of a higher range than had so far been encountered. From the summit of this pass eager eyes beheld streams pouring *away* from their feet—no longer *toward* them, and uniting into a river-way flowing broadly toward the sunrise. First of all men they stood on the watershed of the continent—the Great Divide—and were at the springs of the Missouri-Mississippi rivers.

Picture the mingled pride and wonderment and rejoicing in the hearts of these primitive pioneers! They could see at the base of the range a spacious valley. They would turn their backs to the heights, to the dangers they had endured, would go down to its green expanse, would camp there until those behind them had caught up. But first two things had to be done—messengers must be sent back with the wonderful news, and a huge fire and smoke must be made, to learn by it whether or not the far vista before their eyes held any sort of humankind. No response was visible, and so assured that no enemies awaited them they abandoned any fear about descending the big river as far as it would lead. So they did, and a goodly host followed, and possessed the land in peace.

Let us pause for a moment to suggest what no doubt was happening elsewhere. It may well be believed that during these foregoing years or centuries, part, at least, of the growing mass of inhabitants left on the Pacific Coast had pushed southward, had formed more southern passes across the mountains, had found such rivers as the Platte, the Arkansas and others leading them across the Great Plains; while many, after occupying California, had even followed the Pacific verge into Mexico. Unless, as geologists may show us is the case, a moister climate prevailed then from southern California to Texas, few even of daring scouts would yet have reached the Gulf of Mexico; that discovery more

likely remained for those who ultimately descended the Mississippi. Such episodes and divagations in ethnic dispersal—early movements in the slow spread of a race through thousands of years toward the Atlantic border of their wide domain-to-be—are properly surmised.

Nevertheless, it is my opinion that the main stream of exploratory migration from the Pacific Coast eastward followed in general the course I have sketched. The Columbia-Missouri route has seemed to me to be logical as that by which the unknown interior of the continent would most easily be reached and examined. From the mouth of the Columbia a continuous water-way, navigable for canoes (in which women and children and their meager baggage might be safely transported) led almost to a feasible passage over the supreme mountains; at this point began a noble river, inviting, fairly encouraging, hopeful travel by its smooth current through a smiling terrain. Does a study of the present-day map show any transcontinental route more natural or practicable than this for such emigrants as I have reasonably pictured?

These Neoliths, having crossed the Great Divide and daring to go on, had no alternative but to follow the Missouri—at any rate until their descendants had reached the pleasant prairies and bountiful forests of the Mississippi Valley. Along water-courses, alone, could the aborigines investigate the land—the vacant, guideless land "behind the mountains." By their banks only could they find the edible plants and fruits, the fish and game on which they must depend for food, and for their sole line of retreat if necessary. The rivers were the natural pathways of discovery, and the safe and desirable places for settlement by those who followed the exploration. But these facts imply the possession of boats. And the only boat possible to their powers was the dugout. They had neither materials nor tools for anything else; but with sharpened stones and the keen edges of the shells of river-mussels, tree trunks could be shaped into serviceable boats. To the aborigines, as it has been ever since (before the horse was given to him) his dugout was indispensable in his domestic maintenance; often it was necessary to success in hunting, trading operations or in the constant warring that was the mainstay of tribal coherence; and upon it he expended the highest skill and ingenuity his situation required, together with whatever of art he possessed. Without their dugouts the ancestral Indians might never have been willing to march on until the race had spread from the Columbia to the Hudson.

A STUDY IN THE DEMOGRAPHIC DISTRIBUTION OF CULTURAL ACHIEVEMENT

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In the educated world there probably is no one who will deny that the greatest phenomenon of our era is the rise and growth of our western culture and, likewise, no one who does not feel that this culture is a precious thing to be cherished and defended in order that it may maintain its vigor and continue to flourish. That this hope will be realized is not at all certain. We recall that many cultures have risen and flourished in the past only to fall into decay and end in destruction, and that among us to-day there are philosophers who believe that our present culture already is tottering toward a twilight from which there will be no return.

Be that as it may, the present social and political unrest the world over has set many of us to ask anew: What is this thing called western culture, whence did it rise, where is its present center of greatest activity, where are its bounds, who are its enemies and what are the forces that threaten its destruction? Volumes have been written on these themes, but the answers are still incomplete.

Since earliest times man has been aware of group differences among his kind. For centuries he has inquired into the nature of these differences and into their underlying causes, which of them are hereditary and which, if any, are acquired by environmental influences; and of all these, which hinder and which help toward the progress and the happiness of the group in which they are found? Geographical location, prevailing climatic conditions, peculiarities of soil, food and water supplies, endemic diseases, prevailing constitutional habitus and the organs of internal secretion especially dominating the individuals of a people—all these have been the topics of analyses and searching scrutiny.

It goes without saying that the most reliable of all these studies are those that have been carried out with the spirit and the techniques of modern science. Now there are two fundamental factors upon which the scientific approach to any problem is based. The first is the possession of a reliable measuring device, a unit that can be applied for the determination of the quantities of any chosen character or property of the thing to be studied. The second is the choice of a character or property which is really worthwhile measuring. The degree of success attained with the first depends upon the limits of accuracy demanded of (and realized in) the measuring device adopted and the skill and the intelligence of the one making the measurements. The degree of success with the second factor in most cases only becomes apparent long after the work is done; now and then its value becomes apparent at once and the author is acclaimed a genius among his peers.

Perhaps in no field of demography have the difficulties been greater in choosing characteristics worthwhile studying and finding appropriate rods to measure them with than in that branch which undertakes to evaluate the relative spiritual and intellectual, or the cultural, achievements of a people. With the hope that some of the questions men ask about our western culture may be answered by its use, the following description and application of a yardstick for cultural achieve-

ment is offered for consideration. The results of the measurements seem to point to certain conclusions which finally are given brief discussion.

The objects, or characteristics, measured in this study are (a), the number of Nobel Prizes awarded; (b) the number of citations in the International Who's Who for 1937; and (c) the number of record-holders and points won by place winners in the Olympic Games, per each ten-millions of the total population of all the countries represented in each category of achievement. This gives a unit of measure for each category which when multiplied into the population figure of any given country will give the number of points it might have under ideal conditions, in other words, the expectation of merit under ideal conditions in any one of the three fields of cultural achievement here considered. What the actual status of any country happens to be at the present time in any one field then may be found (and this is the yardstick finally to be applied) by dividing the actual number of points standing to the credit of the country by the number of points it should have under ideal conditions. Put in the form of an equation this statement would be,

$$\text{Cultural Status} = \frac{\text{Actual Achievement} \times 100}{\text{Ideal Achievement}}$$

The Demographic Distribution of the Nobel Awards

The five prizes announced for the year 1937 by the committees of the Nobel Foundation[1] bring the number given, since the first in 1901, to a total of 159. One may now assume that, if talent and genius were equally distributed and if the cultivation of the arts and learning (in which the prizes are given) were universal among peoples, then one could say that most probably the Nobel Awards also would be distributed among nations nearly in proportion to their respective population figures. Granting this assumption, one may proceed to estimate the ideal rating for each country by the method described above. This has been done for all those countries which have the distinction of having had one or more of its inhabitants designated as Nobel Laureate. The results of the computation appear in the first three columns of Table 1. As will be seen, the figures representing the actual and the ideal allotments tell quite different stories. Germany, Great Britain, France and the United States of America have received in absolute numbers by far the greater share of the awards. But on the population basis of distribution they have received only one to three times their ideal allotments, whereas Denmark, Norway, Sweden and Switzerland all have been awarded ten times their ideal allotments.

The Demographic Distribution of the Citations in The International Who's Who

Recently Captain Frank B. Littell has published an article[2] in which are given the results of his analysis of the numerical representation of the principal nations of the world in the International Who's Who for 1937, "a valuable work of reference containing brief biographical sketches of about 19,000 persons, considered by its authors to be of international prominence."

Here again one may assume that were the people of all lands equal in intelligence, opportunity and training, then the number of biographical sketches in such a work would be pretty nearly in proportion to the population figures of the countries from which they are selected. The actual then would tend to approximate the ideal distribution.

[1] For a brief history of the origin of the Nobel Foundation and a comparative study of the distribution of the prizes see: Harrison Hale, The Scientific Monthly, 40: 157, 1935; *ibid.*, 45: 412, 1937.

[2] Frank B. Littell, *Science*, 86: 476, 1937.

TABLE 1

DEMOGRAPHIC DISTRIBUTION OF NOBEL PRIZES AND BIOGRAPHICAL SKETCHES IN THE INTERNATIONAL WHO'S WHO

Political groups	Population in ten millions	Distribution of Nobel prizes		Distribution of biog. sketches	
		Actual	Ideal[a]	Actual	Ideal[a]
Germany	6.46	37.0	11.30	8.2	5.40
Great Britain and all Ireland[b]	4.89	26.5	8.55	17.3[c]	4.06
France	4.09	19.5	7.15	9.1	3.30
U. S. of America and Canada[b]	13.24	19.0	23.15	16.2	11.00
Sweden	0.61	10.5	1.07	3.3	0.51
Holland	0.78	6.0	1.36	2.1	0.65
Switzerland	0.39	6.0	0.68	1.6	0.33
Austria	0.67	5.5	1.17	1.6	0.56
Denmark	0.35	5.5	0.61	2.3	0.29
Belgium	0.81	4.5	1.41	1.3	0.68
Italy	4.15	4.5	7.25	3.7	3.44
Norway	0.27	4.5	0.47	1.5	0.23
India	32.56	2.0	56.80	1.3	27.00
Poland	2.72	2.0	4.75	2.1	2.26
Russia and U. S. S. R.	14.70	2.0	25.70	1.5	12.22
Spain	2.28	2.0	3.98	1.2	1.90
Argentina	1.09	1.0	1.91	0.19[c]	0.91
Hungary	0.87	1.0	1.52	2.2	0.73
Totals	**90.93**	**159.0**	**159.0**		
Finland	0.36			1.1	0.30
Australia	0.71			2.1	0.58
Yugoslavia	1.34			1.6	1.13
Czechoslovakia	1.47			1.7	1.22
Japan	7.67			2.6	6.30
Totals	**103.48**			**86.1**	**84.5**

[a] For the method of determining the ideal allotment the reader is referred to the text.

[b] The author has taken the liberty, for the sake of simplification, of putting Great Britain and Ireland into one, and The United States and Canada, into another group. Their individual ratings, when taken separately, are much the same as they stand, as groups.

[c] The author is indebted to Captain Littell, *loc. cit.*, who in a personal communication supplied the data on Ireland and Argentina.

From the data in Captain Littell's article one easily determines the distribution of entries per unit of population and then the ideal allotment for each country. The results appear in the last two columns of Table 1, where again it is seen that for the most part the smaller countries of northern Europe lead the list in realizing on their ideal allotments.

THE DEMOGRAPHIC DISTRIBUTION OF THE WINNERS IN THE MODERN OLYMPIC GAMES

The revival of the Greek Games, putting them on a world-wide basis, no doubt has been helpful in the promotion of international understanding and appreciation. Incidentally the games furnish us with numerical data which can be used in this comparative study of the cultural achievements of peoples.

Such a use of the data has been already begun by the present author[3] with the scores won by the first three place-winners in the 1936 Olympiad. The results in that limited study indicated that the smaller countries of northern Europe, for the most part, did better in realizing on their ideal allotments than did the rest of the world.

Since we have seen above that these same countries of northern Europe indubitably excel in the arts and sciences, the question of their excelling also in athletic prowess becomes of particular importance at this point. For, as is well known, it has long been held by many leaders of educational thought that excellence in artistic and intellectual abilities among a people go hand in hand with excellence in athletic ability. This belief,

[3] Charles D. Snyder, THE SCIENTIFIC MONTHLY, 43: 372, 1936.

however, has been based chiefly upon qualitative evidence. Will a more extensive study of the material on athletic achievements bear out the findings in the study of the more restricted data of the 1936 Olympiad?

To answer this question it was decided to make first a study of the distribution of record-holders in all the Olympiads which are still in force; for it was considered that record-holders in the world of athletics are somewhat analogous to Nobel Laureates in the world of arts and sciences. Second, instead of limiting the study to only the first three place winners, as was done in the earlier work, it was decided to extend it to include all six place-winners in all the events of the 1936 Olympiad. The reasons for this extension are the following: first, all place-winners in all events represent a greater variety of ability and more individuals "of international prominence," more analogous to the variety of abilities represented by the citations in the International Who's Who; second, the last Olympiad is chosen because in that year the variety of sports and the number of nations competing were greater than in any previous Olympiad.

The data on record-holders will be found in the World Almanac, N. Y., 1937, and extend over the six Olympiads held between the years 1912 to 1936 inclusive. By the end of the 1936 games, records had been established in 116 different events, the holders representing some 856 millions of people. The ideal allotment for each 10 millions of population therefore is nearly one and one third

TABLE 2

THE DEMOGRAPHIC DISTRIBUTION OF RECORD-HOLDERS (1912–1936) AND PLACE-WINNERS (1936 ONLY) OF THE OLYMPIC GAMES

Group	Population in ten millions	Record-Holders			Place-Winners		
		Ideal	Actual	Per cent. of ideal realized	Ideal	Actual	Per cent. of ideal realized
Finland	0.36	0.49	9	1837	2.26	17	752
Estonia	0.11	0.15	2	1334	0.69	6	870
New Zealand	0.15	0.20	1	493	0.94	10	1063
Hungary	0.87	1.18	7	593	5.45	44	808
Sweden	0.61	0.83	4	482	3.82	30.5	793
Holland	0.73	1.06	6	566	4.89	24	492
Austria	0.67	0.91	3	330	4.26	26	610
Switzerland	0.39	0.53	1	189	2.45	10.5	429
Germany	6.46	8.77	22	251	40.50	134	331
Norway	2.27	...	..	...	1.69	9	532
Argentina	1.09	1.48	2	135	6.83	16	234
U. S. of America and Canada	13.24	17.98	29	162	83.00	86.5	104
France	4.09	5.55	6	108	25.60	35	137
Italy	4.15	5.62	6	107	26.00	35.5	137
Czechoslovakia	1.47	1.99	2	100	9.22	9	98
Egypt	1.42	1.93	1	52	8.90	7.5	84
Great Britain and all Ireland	4.89	6.62	4	61	30.66[a]	20.5[a]	67
Chile	0.43	0.59	1	107	....	..	..
Belgium	0.81	...	..	...	5.08	5	98
Denmark	0.35	...	..	...	2.19	2	91
Poland	2.72	3.69	1	27	17.05	11	65
Japan	7.67	10.40	7	67	48.10	11	23
Uruguay	0.18	...	..	...	1.18	1	89
Mexico	1.48	...	..	...	9.28	8	86
Turkey	1.37	1.86	1	54	8.60	1	12
Yugoslavia	1.34	...	..	...	8.40	2	24
Rumania	1.90	...	..	...	11.90	1	9
India	32.56	44.10	1	2	204.00	10	5
Totals[e]	**91.83**	**115.93**	**116**		**572.89**	**573**	

[a] This figure is based on the scores accredited to Great Britain only, Ireland not having entered the lists in 1936.

[e] Of the total population, as given in Table 2, only 855.9 millions apply in the computations for record-holders, and 916 millions in the computations for place-winners. By theory the totals of ideal and actual allotments should equal each other in each category. The discrepancies between the totals in this respect indicate the degree of accuracy obtaining in the calculations.

TABLE 3

SUMMARY OF RATINGS EXPRESSED AS PER CENT. OF THE IDEAL ALLOTMENT AS REALIZED BY THE ACTUAL ALLOTMENT*

Political groups[f]	Nobel prizes (1901–1937)	Biographical sketches, intern. W. W. (1937)	Olympic games (1912–1936)	Average of all three ratings
Sweden	987	650	638	758
Norway	1048	670	266	636
Switzerland	1138	495	309	625
Denmark	1112	794	46	622
Finland	0	367	1295	554
Holland	443	323	529	432
Austria	470	286	470	409
Estonia	0	10[g]	1102	371
Hungary	66	306	701	358
Great Britain and all Ireland	298	434[h]	64	265
New Zealand	0	5[g]	778	261
Germany	328	152	291	257
France	273	276	123	224
Belgium	318	191	49	190
U. S. of America and Canada	82	147	133	121
Italy	62	107	122	97
Argentina	53	20[h]	185	87
Czechoslovakia	0	139	99	79
Poland	42	93	46	61
Yugoslavia	0	142	12	52
Spain	50	62	0	37
Russia and U. S. S. R.	8	12	0	7
India	4	5	4	4

[f] The order of listing the various nations in Table 3 is determined by the order of excellence, as indicated by the average of all three ratings and as shown in the last column of the table. Of the nations who failed to score in any one of the three categories only those who were honored with the Nobel Prize distinction, or who did exceptionally well in at least one of the other two categories, are included in Table 3.

[g] This figure is based partly on an arbitrary datum, the exact one not being at hand.

[h] See footnote c, Table 1.

* The mean of the per cent. of ideal realized by actual records and by all-events, as given in Table 2, gives the general mean-rating in sports for each country.

record holders. The results of this part of the study are assembled under the caption of "Record-Holders" in Table 2.

The data used as a basis for the study on the distribution of place-winners were published by the Associated Press on August 16, 1936, and represent 28 nations with a total population of nearly 926 millions. A total of 573 points were accredited to those individuals, taking first to sixth places inclusive, and to whom were assigned arbitrarily merits of 10, 5, 4, 3, 2, 1 points, respectively. The results of the computations on these data also appear in Table 2, last three columns. On account of the greater number of entries and points entering into the calculations, the final results differ somewhat from those obtained in the earlier study;[4] nevertheless, the main features of the findings in that study remain unaltered.

We have now compared the actual and ideal distributions of merit in three quite different categories of achievement. The ratios of the two distributions will become much more apparent if we put them in terms of per cent. This has been done for record-holders and place-winners separately for the games, as will be seen in columns 5 and 8 of Table 2. In order to put the merits in games in a single figure the mean of the ratios in these two columns finally is taken for each country. In Table 3 are shown the ratios of actual to ideal allotments of merit in all three categories of achievement. Finally a mean is taken of all three ratios, as shown in the last column of the table. This mean rating in all three categories of achievement establishes an index of the order of excellence in cultural achievement among the various groups. The order of listing them in this table was determined by this order of excellence.

Certain comments on the data used

[4] *Ibid.*

appear to be called for at this point. First, it may be thought by some that the gentlemen sitting on the Nobel Prize Committees, being after all merely human, would not be quite impartial and now and then would give the preference to Scandinavians. Similarly, the editors and publishers of the International Who's Who, being British, and their book being printed in the English language (and therefore destined to be used mostly by English-speaking peoples) the judges inevitably would select a preponderance of names from the lands where the English language prevails.

To offset these misgivings it is only fair to state that, since no specific evidence exists to support them, we must believe that everything has been done to insure a selection of only competent, upright and fearless judges and that those selected have performed their duties to the best of their abilities. It is well known that the judges for the winners of the games were selected from various nations and further, that the automatic devices employed in many of the events were beyond the reach of personal bias and human frailty. But most important of all for the present investigation is the fact that the judges in any one of three fields had nothing whatever to do with the decisions taken by the judges in the other two fields af achievement.[5] It is this last fact that gives our data, when taken all together, a high degree of objectivity and impartiality.

As one scans the results summarized in Table 3, one notes a striking tendency for the order of excellence among the various countries to remain somewhat the same in all three ratings. The outstanding exceptions to this tendency are Finland, Estonia and New Zealand, who, although they have been awarded no Noble Prizes, appear as fifth, eighth and eleventh in the order of averaged ratings. Hungary, who just has been honored with a Nobel Laureate (1937), ranks ninth; Denmark, ranking very low in games, does so well in the other two categories that she still occupies fourth place in the averaged ratings.

On the whole, however, it appears that the general conclusions, drawn in the limited study on the demographic distribution of the first three place-winners in the 1936-Olympiad,[6] also hold in this more extended study. It becomes desirable therefore to restate and to somewhat extend those conclusions.

1. Our yardsticks being European in kind and used to measure occidental rather than oriental ideals of culture, we are not permitted to conclude that the oriental countries standing low in our lists would also therefore stand low in their own kinds of culture measured by their own yardsticks. This study pretends to say nothing in that particular. We can only admire them for having accomplished what they have in our science and games.

2. If figures can add anything to what, because of many other considerations, already has been believed, the present center of occidental cultural achievements lies in western and in northwestern rather than in southwestern Europe.

3. Comparing the ratings in artistic and intellectual with those in the athletic achievements gives definite statistical confirmation to the belief that peoples who excel in the one excel also in the other fields of achievement.

4. It is not the larger but rather the smaller nations of northwestern Europe which excel beyond all others. Mere size of population or spread of empire seems to be no guarantee of the highest mean level of cultural achievement among a people.

[5] The exception to this statement would be the names of Nobel Laureates among the biographical citations. But their number, 159, affect the drift of the 19,000 citations very slightly.

[6] Charles D. Snyder, *loc. cit.*

5. A full explanation of this supremacy of the smaller states will be had only after extensive scientific researches along several lines of which the present author has not the command. But having raised the query, the following brief prolegomenon of the outcome of such researches may be permitted.

At the outset one may say without fear of contradiction that those peoples who satisfy so well our measures of cultural achievement will be found to be made up of less divergent varieties of *homo sapiens* than are those of the less successful groups. The prospective corollary to this proposition doubtless also will be found to hold; namely, that amongst a people where the individuals diverge too greatly in blood and breeding there will be extreme diversity in temperament and conflict of ideals, less balance between dreaming and doing, between debate and decision, more time lost in planning and performing.[7] This state of affairs will lead to constant futility and frustration, so that, even in groups where intelligence is inherently at a high mean level, interest in the social welfare will fail to develop. Amidst their confusion the individuals in such groups will fail either to recognize, or to unite in furthering, the things in life most worthwhile. It is such groups as these who do not know what they want or where they are going.

To begin with then what shall America, what shall all nations of the western world do, who wish to prolong their cultural ideals and national existence? In view of all the foregoing it seems that among the first things to do is to abandon the prevalent timidity and reluctance toward an open discussion of race problems, and of a eugenics which aims not only at the eradication of hereditary (as well as endemic) diseases and low-grade mentalities, but includes also a thorough consideration of hereditary mental attitudes and behavior patterns. Our sex problems have vastly improved since they have been brought out into the open; our race and eugenics problems will likewise benefit by bringing them out into the light. It is superfluous to add that such discussions, to be tolerable and effective, always must be kept on a dispassionate plane.

Since the majority of our people are of northwestern European origins, it is quite reasonable that the control of affairs should finally rest in the hands of leaders selected from such stocks. It is also quite clear, however, that if those, who should be leaders and in control of affairs, become mere onlookers,[8] they will then have only themselves to blame whenever they fall into the hands of minorities.

There is some indication that these minorities are already on the way toward the control of affairs. But if now, before it is too late, our somnolent majority will arouse itself and give full consideration to public affairs it might decide finally to take measures for the maintenance and improvement of the quality of our population by (1) limiting immigration exclusively to selected stock of northwestern European origins, (2) legislating more rigorously against interracial marriages, (3) promoting more diligently enlightened sterilization laws, and (4) adopting policies, which, on the basis of proportional representation, favor individuals and groups who innately sympathize with and give most intelligent support to the ideals of our western culture. Perhaps then all this still may be accomplished in peaceful ways and within the frame of a democracy.

Perhaps then even America will know finally what she wants and where she is going.

[7] For further discussion of this, see Madison Grant, "The Conquest of a Continent," N. Y., 1934, Chapter 18.

[8] John R. Tunis, *Atlantic Monthly*, August, 1937.

THE THEORY OF THE GENE[1]

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MORE than thirty years of experimental research in genetics have established the fact—as it seems, beyond discussion—that the fundamental unit of heredity is the gene. Some biologists call the gene even the unit of life, meaning that the existence of the living world is unimaginable without the existence of the gene. A lecture on the theory of the gene is therefore expected to discuss the facts which led to the conception of the gene as the hereditary unit and, maybe, of possible objections to these facts. The discussion might be extended to the possibilities of understanding the nature of the gene, and in this connection also the problems concerning the action of the gene in controlling development might be included. But the title of this lecture is meant in a different sense. What we intend to discuss is not the existing classic theory of the gene, but the reasons why we believe that this classic theory is no longer tenable and has to be superseded by something else.

There have always been biologists who were sceptical regarding the classic theory of the gene as a hereditary unit. Johannsen, himself, who coined the term—though the actual conception goes back to Roux, Weismann and De Vries—did not like to think of the gene as of an actually existing unit. But he was also opposed to the chromosome theory of heredity. Actually, his scepticism was completely sterile and therefore not justified in his time, when every single fact which had come to light forced the theory of the gene as an actually existing unit upon the minds of geneticists. There were also other biologists who opposed the theory of hereditary units on general grounds. They had to disregard all known facts of genetics in order to prove their point and were therefore in the wrong even if it should turn out now that their sterile scepticism in the face of overwhelming facts had happened to put them after all on the right side.

Any text-book of genetics will convey the information upon which the theory of the gene as a hereditary unit is based. The elementary facts of Mendelian heredity show that the things which control hereditary traits are distributed according to chance and that they may be recombined according to chance without ever losing their identity. When it became known that the behavior of the chromosomes in the sex-cells paralleled exactly the distribution of hereditary traits among the progeny, these traits appeared to be based upon something located in the chromosomes. Then came the discovery that more such unit traits could be traced in one species than the number of chromosomes would permit. This meant that more than one unit character is located in a chromosome and that such a group of characters is expected to be linked in heredity. The next step was the discovery that this linkage could be broken by crossing over and that this exchange between homologous chromosomes could occur at each single locus, *i.e.*, for every single representative of a unit character in the chromosome, called a gene. This meant that small units, responsible for the individual linked traits, must be contained within the chromosome and that these must have a real existence, as they may be shuffled around. Then the law was found that the amount of cross-over is a function of the distance of these units within the chromosome, which in its turn required a linear arrangement of the units. It followed the

[1] Lecture delivered before the University of California chapter of Sigma Xi, November, 1937.

discovery that the same number of linkage groups is found as the haploid number of chromosomes. Then came the discoveries of exchanges of parts of chromosomes (translocations), deletions of parts (deficiencies), inversions of parts; and in every case the actually found consequences were those which could be predicted on the basis of the theory of the gene, *i.e.*, of the existence of units arranged in an orderly bead-like seriation along the chromosome. All these facts could be brought to light because one of the fundamental properties of the supposed units, the genes, turned out to be their ability to change by the process of mutation. This change in the gene leads to a mutant character which may be followed up in crossing experiments, again behaving as a constant unit. It is clear that actually only the mutated gene is accessible to experimentation. But as the hereditary behavior of each mutant gene requires the existence of something, called the wild type allele, at the same point of the chromosome in the normal (wild) stock, mutation must be supposed to have changed a wild type gene into the mutant gene. It further became known that one and the same gene may mutate into a series of alleles (multiple alleles) which again requires the existence of a unit, the gene, capable of a series of changes into other (and again stable) units at the same point of the chromosome. The last touch was given to the classic theory of the gene when it was found that gene mutations may be induced experimentally by x-rays and other agencies and, further, that practically all the details of gene arrangement, as derived from genetic experimentation, could be confirmed cytologically in the giant salivary chromosomes of Drosophila.

This immense body of evidence then showed that units called genes exist at definite points of the chromosome, units which are stable, which can be shifted here and there without losing their identity, which exercise a constant effect upon the developing organism, and which may change spontaneously or under experimental conditions into another stable unit by mutation.

Many hypotheses were evolved regarding the nature of the gene. Though some cautious biologists spoke only of a locus in the chromosome, the majority formed some kind of an idea regarding the nature of the gene, and a great many geneticists have spoken their mind on this point. We do not intend to review these ideas, which in each instance were prompted mostly by such facts as were foremost in the minds of the respective authors.[2] In a general way we may state that the gene was assumed to be a single molecule or a group of molecules of some active substance, probably an autocatalyst. Mutation was assumed to mean either a change in the number of molecules characteristic for the gene, or a change in one side-chain, or a change to a stereoisomere or even a larger change of molecular order. When it became known in recent times that the fibers are composed of micellar compounds of long chain-molecules, a similar constitution was also ascribed to the gene.

The first difficulty arose for the classic conception when the so-called position effect was discovered. Sturtevant found that two Bar eye genes in Drosophila, located in the same chromosome as a result of unequal crossing over, have a different effect from the two B-genes located opposite each other in two homologous chromosomes. He called this a position effect, which would mean that the position of a gene influences its action. This could imply that not only the locus or gene but also the whole chromosome means something for the action of what is called a gene. Recently many

[2] A full review will be found in a book now in press. ("Physiological Genetics," McGraw-Hill Co., New York.)

effects were found which were described under the same name of position effect, though they are absolutely different from the original Bar case. The x-ray technique led to the production of innumerable translocations within the same or between different chromosomes, inversions and similar rearrangements of chromatin material. In many cases they were combined with what appeared to be a mutation at the breaking point or nearby. As such a mutation at the break became less probable with the increase in the number of cases found, the effect was considered by many geneticists to be a position effect. This means that a gene which is put in a new neighborhood, as is the case with a gene adjacent to a break, has another effect than in its normal surroundings, an effect which resembles the effect of a gene mutation, though the gene has not changed at all. If the rearrangement returns to normal, the effect also disappears. To explain this effect within the theory of the gene it was assumed that a part of the action of the gene takes place near its locus. Here, then, the products of its action are most concentrated. If the gene is transferred to another locus these products interact first with something different, namely, the products of the now neighboring genes, and therefore produce a different effect.

It is obvious that this theory of the position effect could save the conception of the gene up to this point. Further facts, however, make it rather difficult. One of the important results of the x-ray experiments was that both gene mutations and chromosome rearrangements were produced in direct proportion to the rate of ionization and independent of wave-length. It was further found that the phenotypes of the gene mutations and of the so-called position effects covered the same characters. But the study of experimental chromatin rearrangements brought another important fact to light. If at (or near) a definite locus of a chromosome anything happens in the way of a rearrangement, an inversion, an insertion of a piece from somewhere else or a deletion, a phenotypic effect may be produced which is identical with the phenotype of the gene mutations, typical for this locus. Anything happening at the Bar-locus may produce a Bar effect. This change then acts in the language of classic genetics like a multiple allele of the respective mutant. It is obvious that it is very difficult in such a case to distinguish between a position effect and a gene mutation. The only difference is that in one case we know that the phenotypic effect is produced by a rearrangement of chromosome material; in the other case we do not know this yet. The suspicion is strong that the gene mutation at the locus in question is also the result of a rearrangement, maybe one which is difficult to make visible cytologically on account of its involving only a very small chromosome section.

There are quite a number of facts existing which lead our thoughts in the same direction.[8] The suspicion would become a certainty, however, if it could be shown that ordinary and typical so-called gene mutations are actually the results of a rearrangement. This now has been demonstrated with certainty for quite a number of standard genes.

The process of spontaneous mutation, as usually occurring, involves the sudden appearance of a single or of a few mutated individuals. We have observed now a series of cases—as it seems, very rare cases—in which something occurs which looks like a strange type of mass-mutation. (One such case has also been found by Plough and Holthausen and actually been termed mass-mutation.) In these cases a whole brood of Drosophila had suddenly changed into a series of mutational types. Thus simultaneously a series of "mutants" appeared in numerous individuals, and some of them turned

[8] See footnote 1.

out to be identical with well-known gene mutations. In this case, however, it could be proven that chromatin rearrangements had taken place spontaneously, which at once produced all these types. Already three major and three minor individual instances have been observed since 1929, and there were produced a large number of "mutants," among them such standard mutants as black, purple, ebony, dumpy, plexus, rudimentary. If this can happen there is no reason to doubt that in due time all other mutants will appear in the same way. To save the gene concept one might still say that all these were cases of position effects and that the original gene mutants were something else. I do not doubt that the not yet completed detailed analysis of these cases will enforce the abandonment of such a last desperate stand. The conclusion, then, is that gene mutation and position effect are one and the same thing. This means that no genes are existing but only points, loci, in a chromosome which have to be arranged in a proper order or pattern to control normal development. Any change in this order may change some detail of development, and this is what we call a mutation. We might of course call a change of arrangement at a locus, a gene. But then there are no genes in the normal chromosome, and the mutant gene has no wild type allele, as the whole wild type chromosome is the allele for all mutant genes in the chromosome. Better, then, give up the conception of the gene except for simple descriptive purposes.

The situation is now this: The whole chromosome is the unit controlling normal development. But in this unit the different points must have a definite order, which is of so complicated a type that most changes of the proper order are either lethal or change the activity of the chromosome in development thus that a different phenotype results, the mutant type. This change of activity with the result of mutant development is, generally speaking, not so mysterious as it may appear at first. We have shown that in Drosophila the phenotypic likeness of the majority of known mutant types may be produced at will by such simple agencies as temperature shocks applied at definite stages of development. These so-called phenocopies then demonstrate that an external and simple quantitative agency can change developmental processes in the same way as an upsetting of the order within the chromosome does. This again suggests that changes of order, if viable at all, result in relative simple deviations from the normal course of events, deviations which probably may be reduced to a large extent to changes in velocities of some integral processes.

If such is the case, we shall have to ask ourselves whether we are facing here in the set pattern of the chromosome something of the order of the mystic "wholeness" which has become so fashionable in the biological literature of certain countries, or whether a chemical model might be imagined which could account for such facts. Actually I believe that such a model is available and that it leads to such interesting comparisons that I may be excused for indulging in a little speculation along this line.

There has already been proposed such a model by Miss Wrinch, which had quite a success with some geneticists. This model, however, still assumes the existence of genes. The chromosome is conceived as a micellar combination of long chains made up of different polypeptids and held together by nuclear acids. The bonds between the different polypeptids are breakage points and anything between two bonds would constitute a gene.

A better, though nearly related model, fulfilling all the requirements made by the facts of genetic experimentation, may be derived from recent work of Bergmann and colleagues upon the constitution of the protein molecule. The facts

which the geneticist wants to be represented in the model are: (a) The ability of the chromosome to reproduce its own image by division or by recreation of its likeness. (b) The point to point identity of two partner-chromosomes as expressed by point to point attraction all along its length. (c) The orderly diversity along the length of the structure of a sufficient complexity to make a change in order in a majority of cases consequential (*i.e.*, change of order equal to mutation). Bergmann starts from certain facts upon which he builds a chemical hypothesis, and both facts as well as hypothesis appear very helpful for our present purposes. The protein molecule is known to consist of a chain of amino acid residues linked by peptide bonds. According to Bergmann these residues are arranged in a simple order. Each amino acid has its own rhythm different from that of the others, and the superposition of all these rhythms produces the pattern of the molecule. The rhythm itself, meaning that one type of residue appears always separated by a definite number of others in the chain, follows a simple arithmetical rule. Thus silk fibroine which contains glycine, alanine and tyrosine residues shows an arrangement of these in the rhythm:

G-A-G-X-G-A-G-X-G-A-G-T-G-A-G-
X-G-A-G-X-G-A-G-X-G-A-G-T-G
(G-G = 2 A-A = 4 T-T = 16)

The total number of members of a chain is 288 or a multiple thereof. To organize such a molecule, a chemical organizer is needed of immense specificity. According to Bergmann, the only known substances with the necessary properties are the intracellular proteinases, which both hydrolyze and synthesize the protein molecule. At this point Bergmann pronounces the hypothesis that the proteinases are themselves proteins. "If the proteinases themselves are proteins and at the same time have the ability to synthesize other individual proteins then there must exist proteinases which have the ability to synthesize replicas of their own structural pattern and therefore are able to multiply in suitable surroundings."

It is astounding to see how these chemical facts and hypotheses fit the requirements for a chemical theory of heredity. Let us assume that the individual chromosome actually is a single immense chain molecule and a proteinase. (This means the essential part of the chromosome—the so-called gene string—to which is added nucleic acid, which makes in some way the stability of the long chain possible. All modern hypotheses regarding chromosome structure have reckoned with these two constituents.)[4] This proteinase then has different properties according to its special surroundings. Either it may produce its own replica, which amounts to a division of the chromosome or it may synthesize other proteins from the parts present or it may hydrolyze proteins. The latter two activities would constitute what is usually conceived as being the function of the gene. The immense specificity of this proteinase is based upon its typical structure. This, however, represents a most complicated though regular pattern, composed of the superimposed rhythms of the different amino-acid residues. This again means that any breakage or rearrangement in the chain leads to a destruction or impairing of the specificity and therefore to other reaction products, which have to be assumed to control the phenotypic changes. Thus it seems that the latest developments of genetics and of protein chemistry permit the statement of a reasonable hypothesis regarding the chromosome, which could easily be elaborated much further.

If the views expressed here should turn out to be correct, a number of far-reaching consequences would become visible.

[4] See footnote 1.

If the chromosome and not the gene is the actually decisive unit, we shall have to revise quite a number of our ideas concerning evolution. In addition we shall have to look at such genetic facts which deal with whole chromosomes from a new angle. For example, in plants trisomics (one chromosome present in triplicate instead of duplicate) have been known to be different from normal diploids and the types produced by the addition of an extra chromosome are among themselves different according to the individual chromosome involved. The fact has been explained on the basis of the theory of genic balance, which is disturbed by an extra chromosome in favor of the genes contained therein. But we know that actually "genes" controlling a definite character (*e.g.*, eye color in Drosophila) are distributed over all chromosomes. The typical differences between different trisomics (different in regard to the chromosome involved) are therefore rather surprising. Still less understood is the fact that different trisomics (according to Blakeslee and Goodspeed-Avery) are distinguished not by different combinations of traits but by the complete habitus of the plant. If no genic balance is involved but the action of a chromosome as unit the facts appear in a different light and their importance increases. Only in passing we might mention that we may possibly also have to change considerably our views regarding sex chromosomes and sex genes.

May I finally point out that the geneticist may furnish the protein-chemist with an interesting fact. In the chromosome there exists a mutual attraction between two and only two identical chains point by point, link by link. The protein-chemist obviously has difficulties in understanding the series of reactions by which a proteinase organizes the pattern of a protein molecule or of its own replica. From the fact just mentioned some information might be derived which would lead to a physical attack upon the problem of organizing or patterning a chain-molecule.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

M-RAYS' EXISTENCE DOUBTED

"Not proven" is the Scotch verdict returned by two critical biophysicists after a careful investigation of the disputed phenomenon of mitogenetic radiation, or M-rays. The two men, Drs. Alexander Hollaender and Walder D. Claus, pursued their researches at the University of Wisconsin for the National Research Council. The council recently published their report.

Mitogenetic radiation, known also by the convenient nickname of M-rays, was first reported by a Russian, A. Gurwitsch, some years ago. He stated that tissues of rapidly dividing cells, such as root tips, emanated some kind of short-wave radiation, of very low intensity, that nevertheless was capable of stimulating other cells to divide also.

Many other investigators, using many methods, have followed the work of Gurwitsch. A favorite set-up is an onion root tip as source of the rays and a small mass of yeast cells as "biological detector."

Although many efforts have been made to detect the rays with mechanical apparatus, such as modifications of the Geiger counter used in cosmic ray work, none of them has ever been successful. This, however, does not necessarily militate against the validity of the observations, for living organisms are still far better detectors of many natural forces than any mechanism yet devised.

However, when Drs. Hollaender and Claus repeated the work very critically, using both physical apparatus and biological detectors and checking carefully every step in every experiment, they were unable to obtain any evidence satisfactory to themselves of the existence of mitogenetic radiation. They therefore rest their case with a negative verdict, at the same time stating their willingness to reopen it again if supporters of the M-ray hypothesis come forward with positive evidence produced under really rigorous experimental conditions.

VITAL CHEMICALS

Certain chemicals, among them phosphorus and the sodium of common table salt, are vitally needed by the body. Medical scientists have known this for some time from observing the disastrous results that occur when these chemicals are lacking from the diet which is the normal source of supply.

Knowledge of the part these chemicals play in the body—phosphorus as an aid in bone-building, for example—has been gained by examining and analyzing the bones and other body tissues after death, and correlating these observations of the amounts of each chemical in the various tissues with the observations of what happens when an animal is deprived of them.

Now scientists can get much more direct information about what happens to some of these chemicals in the body and what they do there. The chemicals are made to put themselves on the spot and show where they are from the moment of entering the body until they leave it. This is done by adding to the substance under observation a bit of the same material, made artificially radioactive. This bit of material can be detected by the powerful rays it is constantly giving off, just as radium itself can be detected by its rays.

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

There is no danger from the artificial radioactive substances because they lose their radioactivity in a short time—fourteen hours in the case of radiosodium. In fact, this makes it necessary for very fast team work between the physicists who endow sodium or phosphorus with radioactivity and the medical scientists who use it for physiological studies.

Besides observing how substances such as phosphorus and sodium are used by the body, scientists, by tagging them with radioactive material, can learn how they are changed by disease and can check on radioactive treatment of cancer. Radioactive substances for such studies are now being produced in quantities by the cyclotron at the University of California under the direction of Professor E. O. Lawrence.

COAL IS STILL POWER KING

Coal is still power king and is the energy source upon which the future must rely, despite the relative decrease in its use that has occurred in recent years.

Natural supplies of oil and gas and the electricity that comes from water power will not in future years supply our needs. Technical experts look forward to the day when coal will supply us not only with the bulk of our power from central stations but with superior synthetic fuels, such as gas for heating, liquid fuels for internal combustion engines, and smokeless solid fuel for home heating.

Inevitably an end to flush production of petroleum and natural gas will arrive, not suddenly but gradually and steadily, a survey made by the Ontario Research Foundation shows. This will be due both to enforced conservation measures and to changes in the economics of the industry. Synthetic manufacture of oil and gas from coal will become more economically justified with increased cost of natural oil and gas. Relatively less coal will be burned raw.

Even now figures show that almost a third of the bituminous coal produced in America is processed. A single coking plant near Pittsburgh consumed one per cent. of all the coal mined in the whole world. Processing of coal, taking out the rich chemicals that dye our textiles, make our medicines, supply raw materials for industries, creating gaseous and liquid fuels and leaving coke for metallurgical and other uses, will inevitably become one of the largest of our industries.

Public health factors and the economic losses due to smoke that blights many of our large cities will demand that smokeless fuels and fuels processed and purified for special purposes be used practically exclusively. Burning untreated coal may be considered almost a crime. We derive our power from the fossil sunshine of past geologic eras. We are living on the energy savings of the past. We are, alas, scattering our power resources over the face of the earth in fine dust and degraded energy.

HELIUM, SUN ELEMENT, SOON TO HOLD AIRSHIP ALOFT AGAIN

Soon the compressors at Amarillo will be whirling full speed handling millions of cubic feet of nautral gas in order that helium, the sun element, may again hold aloft an airship.

Twenty years ago with great secrecy American engineers and chemists converted helium from a "rare" gas, commanding $2,000 a cubic foot, into a noninflammable competitor to hydrogen as a lifting gas for balloons and airships. When the armistice was signed thousands of cubic feet of helium in cylinders were on a New Orleans wharf ready to be shipped for use in the world war.

Now the Germans, the disaster of the hydrogen-filled *Hindenburg* fresh in their memories, are about to use some 18,000,000 cubic feet of helium for the initial inflation and replenishment during flights that the new Zeppelin *LZ–130*

will make this summer between Europe and the United States. America has a monopoly on commercial supplies of helium, and Congress after the burning of the *Hindenburg* enacted a law allowing its sale for restricted commercial, research and medical uses.

The extraction of the 1.8 per cent. helium in the natural gas from the Cliffside field in the Texas Panhandle is the task of the U. S. Bureau of Mines. Underground in the government-controlled gas field that supplies the Amarillo plant there is an estimated reserve of 1,800,000-000 cubic feet of helium, enough for years to come. Some smaller gas fields in Utah that are much richer in percentage of helium have also been set aside and steps are being taken to purchase helium properties near Dexter, Kansas, and Thatcher, Colorado.

Sufferers from asthma and "sandhogs" and deep sea divers who work under pressure will benefit from the availability of helium. The gas is used in preventing the "bends" when under-pressure workers are decompressed. And helium is proving useful in treatment of respiratory diseases.

SOUND-ABSORBING LAYERS OF LITTLE USE IN MOTOR CARS

The amazing sound-absorbing materials which still the clatter and noise of busy restaurants and cafeterias seem to the layman to be the ideal for the job of quieting the interior of his motor car. The reasoning for this assumption is straightforward enough on the thought that what is good for noise reduction in one case is equally good for another.

Acoustical engineers, whose job it is to study sound, wish the problem really were as simple as this. The truth of the matter is that sound-absorbing materials which work so well for stilling noise in a cafeteria or improving remarkably the acoustics of an auditorium are of almost negligible value as a lining for the interior of a motor car.

The reason is that sound-absorbing materials are practically "transparent" to sound. Because they permit sounds to penetrate within them they are highly valuable for noise problems due to sound reflections. This is the type of problem which appears in auditoriums where troubles are most often caused by excessive reverberation or multiple reflections of sound so that one hears the sound prolonged to a confusingly lengthy time.

But the very transparency of sound-absorbing materials makes them ineffective for silencing noises originating outside the chamber they are designed to shield; noises from the engine, from vibration in the frame and other places. To stop such sounds dense, hard materials like glass or steel are best because they reflect the noises more toward the outside. The use of these dense materials, however, permits ready entrance into a motor car's interior of actual mechanical vibrations which can, in turn, create sounds inside. Elastic materials like rubber are employed between separate sections of the body to damp out these mechanical vibrations before they become sources of sound within the car.

NEW SWEDISH PROCESS FREEZES SALT FROM OCEAN

Salt seems so commonplace in America to-day that it is hard to realize that it was one of the economic commodities which played a great rôle in fashioning the ancient highways of commerce. One of Italy's oldest roads is the Via Salaria that linked the salt pans of Ostia with the Sabine country. Even to-day the main part of caravan commerce across the Sahara Desert consists of salt, for in the interior of Africa salt still ranks as precious and retains something of its status of the past when it was used as money.

But one need not go into darkest Africa to find a region where salt is a crucial problem for a nation. There is Sweden. Sweden has no salt and no fuel; the latter

being significant because one can evaporate salt water if an abundance of fuel is at hand for a fire. Yet Sweden has an abundance of hydroelectric power and thereby has one key with which to unlock the doorway which guards the salty waters of its majestic fiords.

Sweden is now building an experimental factory on Gullmar Fiord in which salt will be produced by freezing. The U. S. Bureau of Mines reports that Gullmar Fiord contains a very high percentage of salt in its waters. At the experimental plant this water will be frozen by the abundant electric power in mechanical freezing units and a very concentrated salt solution thus obtained. This salty brine is then evaporated by heat, but much of the work of getting the final salt crystals has already been done by the freezing. Thus the scarcity of fuel can be overcome, in large measure, by Sweden's tumbling torrents.

ELECTRICITY AND SKELETONS PROLONG CIVILIZATION'S LIFE

Electricity, working on myriads of skeletons from which life departed millions of years ago, will do much to prolong the life of our own civilization. This apparent paradox, which modern science makes real and even commonplace, is explained and emphasized in the new annual report of the Tennessee Valley Authority. New processes of making better phosphate fertilizers in electric furnaces promise to revolutionize the whole fertilizer industry, and with it agriculture, and with agriculture the tenure of civilization itself.

But where do the skeletons come in? In the phosphate rock. Indeed, to a very large extent, they *are* the phosphate rock—it consists of thick deposits of ancient animal skeletons, ranging from fish down to one-celled organisms, left on the bottoms of ancient seas and since pressed and hardened into stone.

The electric-furnace method of preparing phosphate fertilizer does two things: it makes a much more concentrated, effective fertilizer, that costs less in freight from furnace to field; and it makes possible the economic utilization of lower grades of rock than can be worked by present methods, and that without the use of sulfur now required. Even without waiting for the full developing of the electric-furnace method, TVA phosphates have been put into wide use in many places throughout the valley and in several states outside. Distributed with the strict understanding that they are for use only in soil-restoring plantings, TVA phosphates are establishing pastures, checking erosion and capturing six pounds of nitrogen from the air for every pound of phosphorus, through the agency of plants which they fertilize.

Important for the power and navigation use of the river itself is the development of the valley phosphorus program. For if the great reservoirs behind the dams fill up with erosional silt, the whole vast project comes to naught. Insuring that water for these reservoirs comes from grass-floored valleys, not from crumbling gulleys, is not the least of the tasks of phosphates from the furnaces of the TVA.

THE FORMATION OF YELLOWSTONE CANYON

Millions of years ago, a river in the Northwest took the "hard way." As a result, to-day millions of tourists stand in awe, every summer, gazing into the pastel-tinted Grand Canyon of the Yellowstone.

The tale is told by Professor Arthur David Howard, of New York University, in a report to the Geological Society of America. The Yellowstone River has its source in Lake Yellowstone, which lies right up against the Continental Divide, in the great national park of the same name. The river flows first north, then west, cutting deeply through a couple of mountain ranges, finally joining the Missouri at Ft. Union on the eastern

boundary of Montana. Thence its waters continue their long journey toward the Gulf of Mexico.

At the southern end of Yellowstone Lake, the Continental Divide is not all the place of rocky steepness its name might suggest. There is a very wide pass —so wide and flat, indeed, that its floor is a wet meadow most of the spring and summer. On the other side are streams that eventually reach the Pacific, by a much easier route. Why did the river take the more difficult way?

The paradox is only apparent. Yellowstone waters also flow downhill; and downhill, in the early days of the river, was toward the north. The mountains were still a-making, and as they rose the river cut through them and kept a way open. During the Pleistocene Ice Age, glaciers apparently blocked the northern drainage one or more times, and the lake did then overflow the divide and drain toward the Pacific. But when the age-long ice-jam went out, it resumed its northerly flow.

The river has not kept in the same channel all the time, Professor Howard found. He confirmed the observations of other geologists who studied the terrain before him, that there is an old channel of pre-Ice Age date, high on the uplands above the present gorge bottom. He also describes a second channel, proved to be of Ice-Age date by sediments of that age found in it. The river now occupies a third, comparatively new channel.

SOUTHERN EUROPE'S EROSION

The goat, irrepressible, omnivorous, cropping every living shoot level with the bare soil, was pointed out as the cause of the age-old soil-erosion problem of southern Italy, Greece and other Mediterranean countries, in a Royal Institution lecture delivered in London by Sir Daniel Hall, director of the John Innes Horticultural Institution.

First, the forests were stripped from the hills, and no provision made for their replacement. Then came the pressure to extend the limits of grazing. "Grazing is all very well if regulated," said Sir Daniel, "but unfortunately in these Mediterranean countries goats are among the chief grazing animals."

"It is no accident that old tradition has represented the Evil One with the hooves of a goat, for of all animals the goat plays the devil with land. Hungry goats will eat anything that grows; they destroy every seedling tree as fast as it gets its head up; they complete and extend the destruction the wood-cutters have begun."

Then comes the cycle all too familiar to Americans who have seen over-grazed land: the animals' sharp hooves cut the surface of the soil; they beat down hard little paths, invitations to runnels of water when the rains come. These become first little gullies, then great gashes, and presently the slope is slashed into badlands. "Such has been the history of much of the fairest land on the seaboard of the Levant," said Sir Daniel. "On the heights bare rock where once forest and meadow flourished, rivers that are torrents in winter and dry in summer, old seaports no longer accessible."

"The destruction of the forest was thus a major factor in the decay of Greece and Rome itself; it means in the first place the loss of farming land and of the agricultural population which formed the backbone of the early armies of the republic."

THE ROLE OF GLANDS IN MENTAL DISEASE

One of the most puzzling problems faced by the scientist exploring man's mind is the rôle played by the powerful glands of the human body. A matter of demonstrated fact is the knowledge that these glands serve as chemical factories, pouring out potent substances capable of changing the whole behavior of the individual. Presence or lack of a glandular chemical may make a person

energetic or lazy, submissive or rebellious, mentally alert or stupid.

That the endocrine glands occupy a place of power in determining the mental soundness or illness of the individual has long been suspected by physicians and psychologists. Glandular disorders have been noted in the mentally ill and to some this has meant that the glands could be blamed for the mental illness. Others, reversing the relationship, see the emotional strains of mental disease as effective in throwing the endocrine system out of balance.

Actually, medical science to-day has no crucial evidence of any cause and effect relationship between the glands of internal secretion and mental disease or mental deficiency, Dr. Hugh T. Carmichael, psychiatrist of the University of Chicago Medical School, told his colleagues at the recent meeting of the American Association for the Advancement of Science.

A recent survey showed that of a group of about 300 mental patients selected for endocrine diagnosis and treatment more than a third were so improved that they were able to leave the institution. Further analysis showed that only 17 per cent. of those selected for endocrine diagnosis actually had anything wrong with their glands, and less than half of these had adequate gland treatment. In addition many of those "cured" had had a type of mental disease that often disappears spontaneously. Mental disease and mental deficiencies are common. So also are glandular imbalances. That they are often found in the same individual could be simply a matter of chance. The rôle of the endocrines is still an unsolved problem and presents a fruitful field for future research.

LENGTH OF LIFE AND FOOD SELECTION

The old adage, man is what he eats, unlike some of the old-time sayings, gets more and more confirmation from scientific research. Length of life as well as health is now said to depend to a large degree on a wise selection of food for the daily diet. This means eating foods every day that contain each of the three great classes, proteins, carbohydrates and fats, and that also contain the important minerals and the popular as well as essential vitamins. Most of us have learned by now that in order to keep well meat and potatoes, bread and butter, eggs, cereal and sugar and cream must be augmented by raw and cooked vegetables and fruits and by milk.

Now the food scientists tell us that eating just enough of these to keep well is only the beginning. Keeping well usually means avoiding ill health. But by eating extra amounts of the foods that contain vitamins and minerals—the protective foods, so-called because they protect against sickness—one can not only avoid sickness but increase vitality and length of life.

In the case of riboflavin, which used to be called vitamin G, scientists at Columbia University have found that an almost infinitesimal amount in the daily diet will keep animals normally healthy and able to reproduce generation after generation. But by increasing the amount of this substance in the diet, the animal's nutritional well-being can be increased to three times the minimum adequate level. The offspring of these animals also benefit to the extent of being four, seven and even ten times as healthy as the minimum standard of health demands.

While the studies were made on laboratory animals, the results may be applied to human animals. The differences in the relative proportions we choose of the staple foods in our daily diets may make enough difference in the body's internal environment to make us immeasurably healthier throughout a lifetime.

POPULATION TO DECLINE DESPITE INCREASES IN PAST

Man power—or brain power—is the

most valuable resource of the world, for out of it arises civilization and culture.

There has been a certain complacency about the renewal of our human resources. The population of the world trebled in the last 160 years. The white races increased from 150,000,000 people in 1780 to 635,000,000 in 1930. That would seem to justify the idea that there is no need for worry about the natural increase in population.

To-day it is possible for the first time to inventory, with some scientific accuracy, man power not only by quantity but by quality as well. Frederick Osborn, of New York City, who has collaborated with Dr. Frank Lorimer on population studies, reported recently to the American Association for the Advancement of Science that the old process of population growth is coming to a sudden stop among peoples living in cities. A period of decline has arrived in most countries of Western Europe.

By using crude birth and death rates, experts as recently as a decade ago found the population appeared to be rapidly increasing. But when the age grouping of the population and other factors were considered, it was found that true rates for 1930 were 16.9 births per 1,000 and 16.3 deaths per 1,000, contrasted with crude rates of 18.7 and 10.8.

The slight excess in the rate of intrinsic reproduction in 1930 above that needed for replacement has been whittled away since that time, Mr. Osborn finds. There is no doubt that the country is at present declining in numbers in the true or intrinsic sense. The best guess of the population students is that the fall in birth rate will continue, and that the gross population will be something less than 150,000,000 in 1970, declining thereafter.

PRESERVATION OF NAVAJO LORE

Science must work fast to get information now stored in Navajo Indian minds, warns Francis H. Elmore, of the State Museum at Santa Fe, who has been querying these Indians on use of various plants.

The Navajo had ideas for using at least 500 plants growing in their Southwestern country. The great outdoors was a shopping center where a Navajo could go for basket materials, for food, drinks, medicines, dyes to brighten a garment, games for the children.

But that's changed. With government aid, and with ways of earning money from blankets, silverware and sheep brought to Navajo attention, these Indians have taken much of their "trade" away from the old plant stores. Conservatives still prefer some of the foods eaten by their forefathers. But Mr. Elmore explains that a Navajo has learned that he can buy food almost as cheaply as he can gather it, and with half the trouble.

Consequently, a young Navajo is little better at describing ancestral customs than a young New Englander might be at telling you how his great-great-grandmother made soap. Some older Indians still have valuable information, but Mr. Elmore warns that "in a few years the Navajo will probably have forgotten how many of the plants were used."

Early Navajo lived chiefly on corn, as these Indians still do, he explains. But whenever war or roving interfered with farming, resourceful Indians could live on seed, roots, stems, and leaves, sustaining themselves even on long journeys. The daring of the traditional first-man-who-ate-an-oyster was matched by more than one Navajo who tasted some scrubby fruit to try its food value.

Study of Navajo ways may yield useful information, Mr. Elmore foresees. The pinon nut, Southwestern Indian fare, has become a commercial article for the white man's market, and other Navajo plants may prove useful to us, as to them.

THE FISH IN THE IRON MASK

AND OTHER FISHES WITH IRON RINGS AROUND THEIR NECKS

By Dr. E. W. GUDGER
ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

In another article[1] I have discoursed of mackerel, bluefish, haddock, gar and needle-fishes wearing rubber bands about their bodies; of a swordfish and a sturgeon each with such a band around its snout; of four dogfish each with a rubber band around its body in the neck region (if such may be attributed to a fish); and finally of a fair-sized shark carrying about with him an automobile casing. In this article, however, I purpose setting out some extraordinary instances of fishes wearing adornments of iron and shell.

THE FISH WITH THE IRON MASK

In August, 1931, the picture reproduced herein as Fig. 1 was published in *Field and Stream*. It shows a 15-pound codfish with its head confined in a syrup can. The fish was discovered in water about six feet deep at Point Fosdick ferry landing on Puget Sound, Washington. It was wriggling about trying to push the can along on the bottom when it was noticed by Mr. A. B. Burnham. Secured easily with a fish spear, it was held up by Mr. Burnham while it was being photographed as Fig. 1 shows.

On examination it was found that the head of the fish was tightly held by the edges of the top of the can where this had been cut to get at the contents. The fish seeking food had thrust its head through this irregular jagged opening, and the hinder bones of the jaws had been caught by the edges of the metal and the fish was a prisoner to the syrup can.

Mr. Burnham noted that the can was covered with barnacles, and hence he thought that the fish had worn this long enough for the barnacle larvae to settle down and grow up. However, there is reason to think that the barnacles might have been there when the fish acquired this unique headgear. But Mr. Burnham's next point is better taken. He found that the *under side* of the can was worn thin and in places clear through, where the poor fish had pushed it along on the sandy bottom. And in the meantime the metal had worn the flesh away clear to the bone in a strip half an inch wide all around the head of the fish. Had the fish been left in the sea water a while longer there would have come about the condition of things to be recounted in the next section of this article.

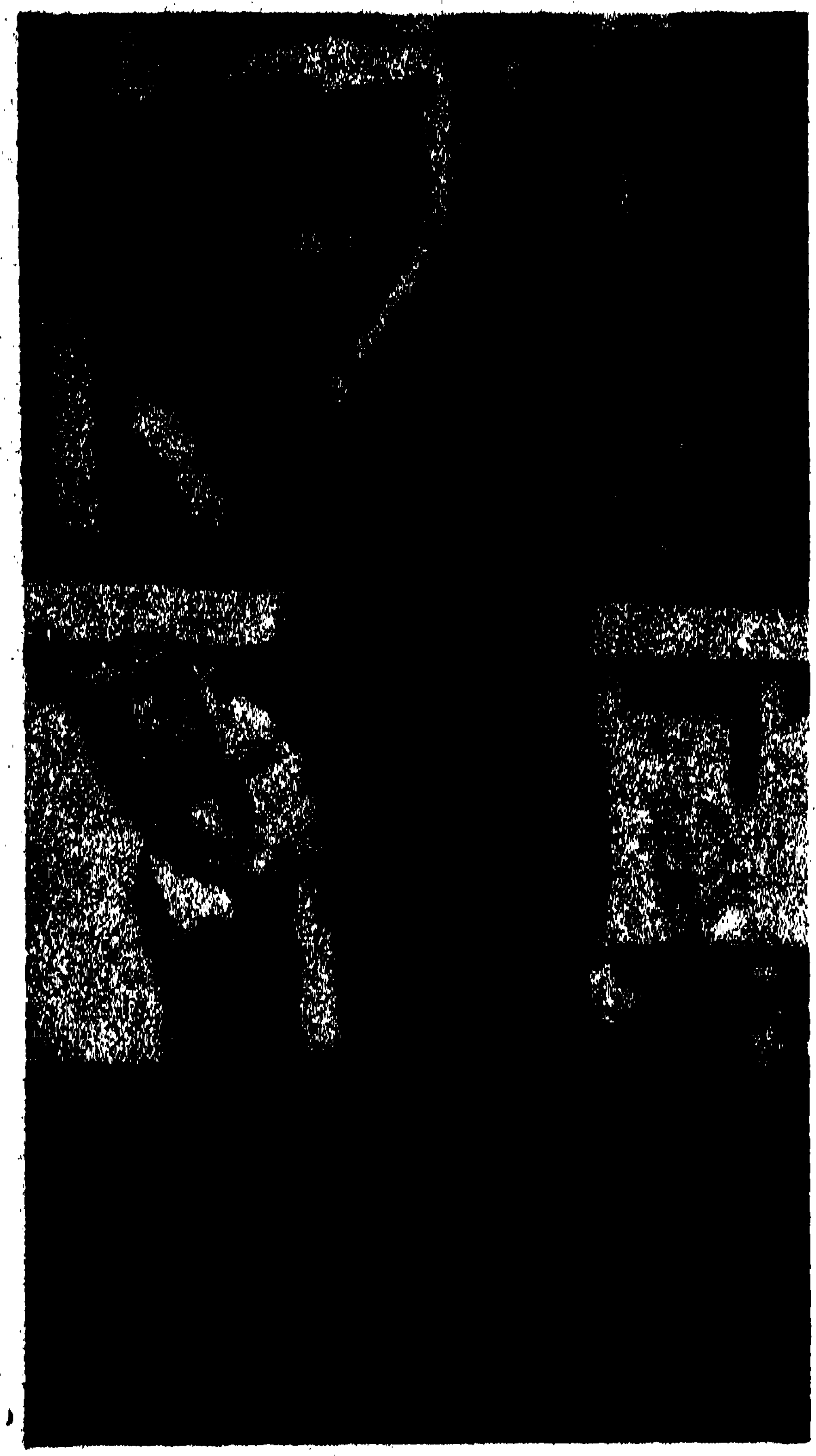
It is interesting to note that this codfish weighed 15 pounds (the length is not given) and was seemingly fat and well-fed. The fish must have managed to feed (probably) on small crustaceans which would go into the can seeking food for themselves, only in turn to become food for the cod. To make this matter easier of belief, I can state that a few mouthless but fairly well-fed fishes have been described by scientific men. These must have gotten their food through the gill-openings.

A CODFISH WITH AN IRON RING

The *Boston Herald* of July 27, 1932, published this interesting item:

> A 20-pound cod with a band of metal round its body was caught by the schooner *Elk* in South Channel and brought yesterday to the Fish Pier. The band, which may have come from a draw bucket such as firemen use, was in fair state of preservation. The fish was three feet long.

[1] THE SCIENTIFIC MONTHLY, December, 1937.



—*Photograph by courtesy of Field and Stream*

FIG. 1. A CODFISH IN AN IRON MASK.

ITS HEAD, THRUST INTO A TIN CAN, HAD BEEN CAUGHT BY THE CUT EDGES OF THE CAN AND HELD FAST.

When Mr. F. E. Firth, a U. S. Bureau of Fisheries man, stationed at the Boston Fish Pier to gather biological data, read this account he went into action. For two days he chased this fish, finally got it and had photographs made. One of these is shown in Fig. 2. At that time Mr. Firth had not got as closely in touch with the Department of Fishes of the American Museum as he has since become, so the fish was not sent to us here. It was large, Mr. Firth had no place to keep it and, as it was not in the best condition, after it had been photographed, measured and weighed, it was thrown away.

Mr. Firth's notes on this fish read as follows:

This codfish measured 36 inches long over all, and weighed 12 lbs. dressed. It was caught from the schooner *Elk* on a line trawl about 55 miles S. S. E. of Highland Light, Cape Cod. The metal band was the top ring (cut edge) of a gallon can. The action of the salt water had rusted away all of the can but the ring. This was around the fish's neck, in front of the pectoral fins, cutting into the pelvic fins (which were nearly cut in two), and it had made a slight groove in the dorsal part of the body.

In the case of this codfish, there is every reason to believe that we have here the last stage of which the first is described in the preceding section and shown in Fig. 1. The sides of the iron bucket or can had rusted away, but the rim, largely made up of other metals in the solder, had resisted corrosion.

This is surely an extraordinary phenomenon. That the band does not make a tight fit on the cod (Fig. 2) is due to the fact that the fish had been dressed, thus considerably reducing its girth. That the fish had carried the ring for some time is attested by the data above set out and also by the further fact that there were some hydroids growing on the ring as shown faintly in one of the photographs sent to me by Mr. Firth. These, when newly out of the water, were from one to five inches long, and must have been on the ring certainly weeks and possibly months.

The Shark with the Iron Ring

Since this article was written my attention has been called to an item in a Nova Scotia newspaper reciting that early in October, 1936, Mr. Arthur Perry, of Roseway, Nova Scotia, had captured a ringed shark. After some correspondence, I got in touch with Mr. Charles D. Hagar, of Roseway, who has talked with Mr. Perry and who has courteously communicated the following facts to me.

Mr. Perry had set his herring net at

—*Photograph by courtesy of F. E. Firth*
FIG. 2. A CODFISH WITH AN IRON RING ABOUT ITS NECK.
IT TOO HAD SHOVED ITS HEAD INTO A TIN CAN, ALL OF WHICH HAD RUSTED AWAY BUT THE RIM MADE OF SOLDER.

the entrance of Shelburne Harbor, Nova Scotia. One morning on going out to "fish" this net, he found caught in it a mackerel shark about 5 feet long and about 4 feet in girth. This he towed ashore and when he began to cut it up he found around its body just back of the gills a stout iron hoop or ring. This being a tight fit had cut its way through the skin and this had on the upper surface healed over the ring. The metallic body was apparently the ring of a 60-pound lard bucket. Unfortunately no photograph was made.

The explanation is conjectural. Presumably a large emptied lard can had been filled with garbage and the whole thrown overboard from some steamer. The shark seeking food had thrust its head into the can and had got it caught therein, as had the fish shown in the first section of this article. Rust presently relieved the shark of the tin bucket but not of the ring made chiefly of solder. This ring must have been around the shark's neck for a long time, long enough for the shark to grow large enough for the ring to become sunk in and covered over by skin if not by flesh. I have elsewhere made record of small sharks with rubber bands around their neck-regions and of a fair-sized shark with an automobile casing around it just in front of the dorsal fin, but this is the first instance known to me of a shark with a metallic ring about its body.

A Trout with a Tin Collar

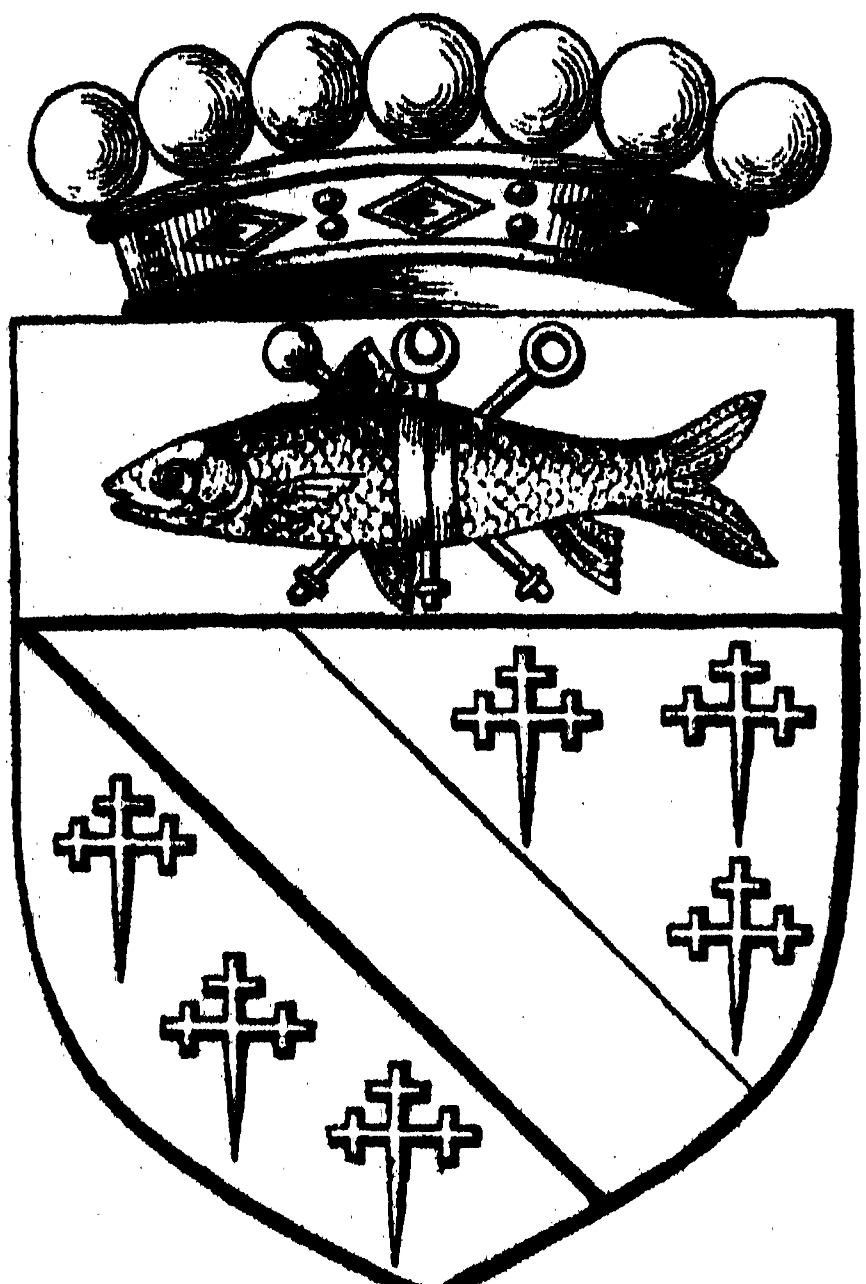
About 30 years ago Old Baldy Lake in the Rio Grande National Forest in Southern Colorado was stocked with trout, and in the year 1929 there was taken from it the remarkable specimen shown in Fig. 3. The fish was caught by Mr. W. M. Rodenbush who sent picture and account in to *Field and Stream*, the well-known sportsman's magazine.

The fish, when hooked, put up no fight —it could not with that tin collar impeding its movements. This collar consisted of the top of what was apparently a tin can. This collar had cut through the ventral side of the fish's body almost to the alimentary canal, and into the back for about a quarter of an inch. However, the fish, which weighed 1¾ pounds, seemed perfectly healthy.

Here again the explanation of this ring is to be found in the conditions shown in Fig. 1. In nosing about for food, the fish had stuck its head into the empty tin can and its body had got caught on the jagged edges of the top where this had been cut to allow access to the contents. These edges had held fast to the body of

—*Photograph by courtesy of Field and Stream*
FIG. 3. A TROUT WITH A TIN COLLAR.
THIS IS ALL THAT IS LEFT OF A TIN CAN INTO WHICH THE FISH HAD ONCE UPON A TIME THRUST ITS HEAD.

the fish, the can had rusted away leaving the rim with the jagged edges of the top embedded in the fish's flesh. Since rusting goes on more slowly in fresh than in salt water, one must conclude that this trout had worn his ring longer than had the codfish described in the preceding section. The trout may have been hard put to it to feed when it first got caught, but, after the body of the can rusted away, it surely found conditions more



—From Moule's Heraldry of Fish, 1842

FIG. 4. AN HERALDIC RINGED FISH.

THE COAT OF ARMS OF VISCOUNT LAKE OF DELHI AND LASWAREE.

favorable. It certainly looks fat and well fed. But it surely is an unusual trout.

An Heraldic Ringed Fish

Fishes with rings in their mouths are not uncommon in heraldry, in armorial bearings and coats of arms, but I have discovered one coat of arms having as a part of it a ringed or banded fish. This is of Indian origin, as will now be shown (Fig. 4).

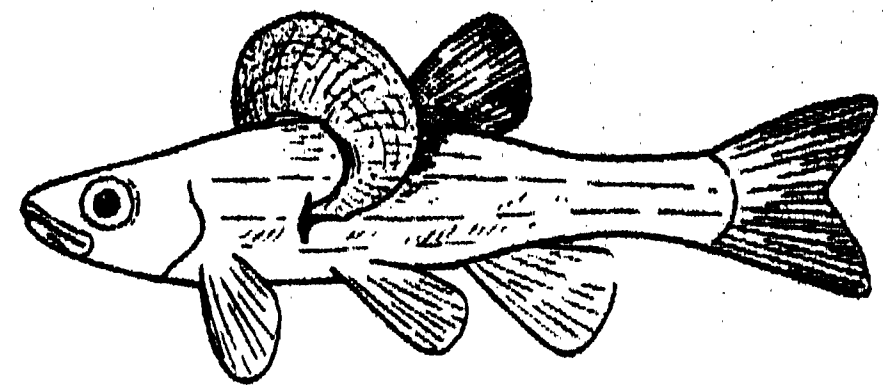


FIG. 5. A FISH WITH A SHELL NECKPIECE.

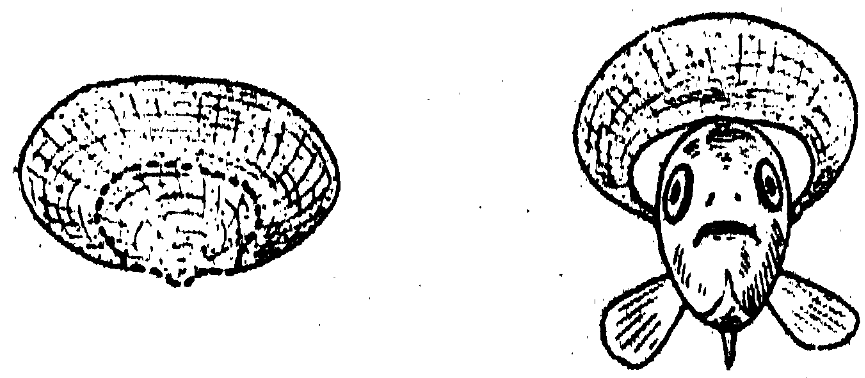
THIS WAS SEEN IN A TANK IN THE NEW YORK AQUARIUM.

The description of this coat of arms in the language of heraldry is:

Sable, a bend between six cross crosslets fitchy argent, on a chief of the last the fish of Mogul, per pale or and vert, banded vert, and gules, surmounting the Goog and Ullum, honorable insignia, in saltier.

This is all Hindoostanee or Urdu to me —especially "cross crosslets fitchy argent," but "fish of Mogul" gives one a hint. This followed out has led to the uncovering of the following interesting information.

Under the name *Mahi Maratib*, the Indian carp, *Cyprinus rohita* (common in Gangetic waters) has long been used as a badge of dignity in India. This fish is represented on the banners of the King of Oude, but it antedates his dynasty and kingdom. It is said to have originated with the Mogul dynasty founded in India in 1206 by Chingis or Zingis Khan. The



—From sketches by Mr. C. M. Breder, Jr.

FIGS. 6 AND 7. HOW THE SHELL NECKPIECE ORIGINATED AND HOW IT WAS HELD IN PLACE.

THE SHELL HAD BEEN WEAKENED BY CHEMICAL ACTION ALONG THE HEAVY LINE AND THE CENTRAL PART HAD FALLEN OUT. THE FISH, THRUSTING ITS HEAD THROUGH THE HOLE IN THE SHELL, HAD GOT THE SHELL FAST TO THE SIDES OF THE BODY JUST IN FRONT OF ITS DORSAL FIN.

Mahi Maratib was chosen because the oriental legend, recited in the Koran, has it that Abraham, after sacrificing on a mountain in the land of Moriah a goat instead of his son Isaac, threw the knife into the water. This struck a carp, and to this day this is the only animal eaten by Mohammedans without its having previously had its throat cut and it blood drained off.

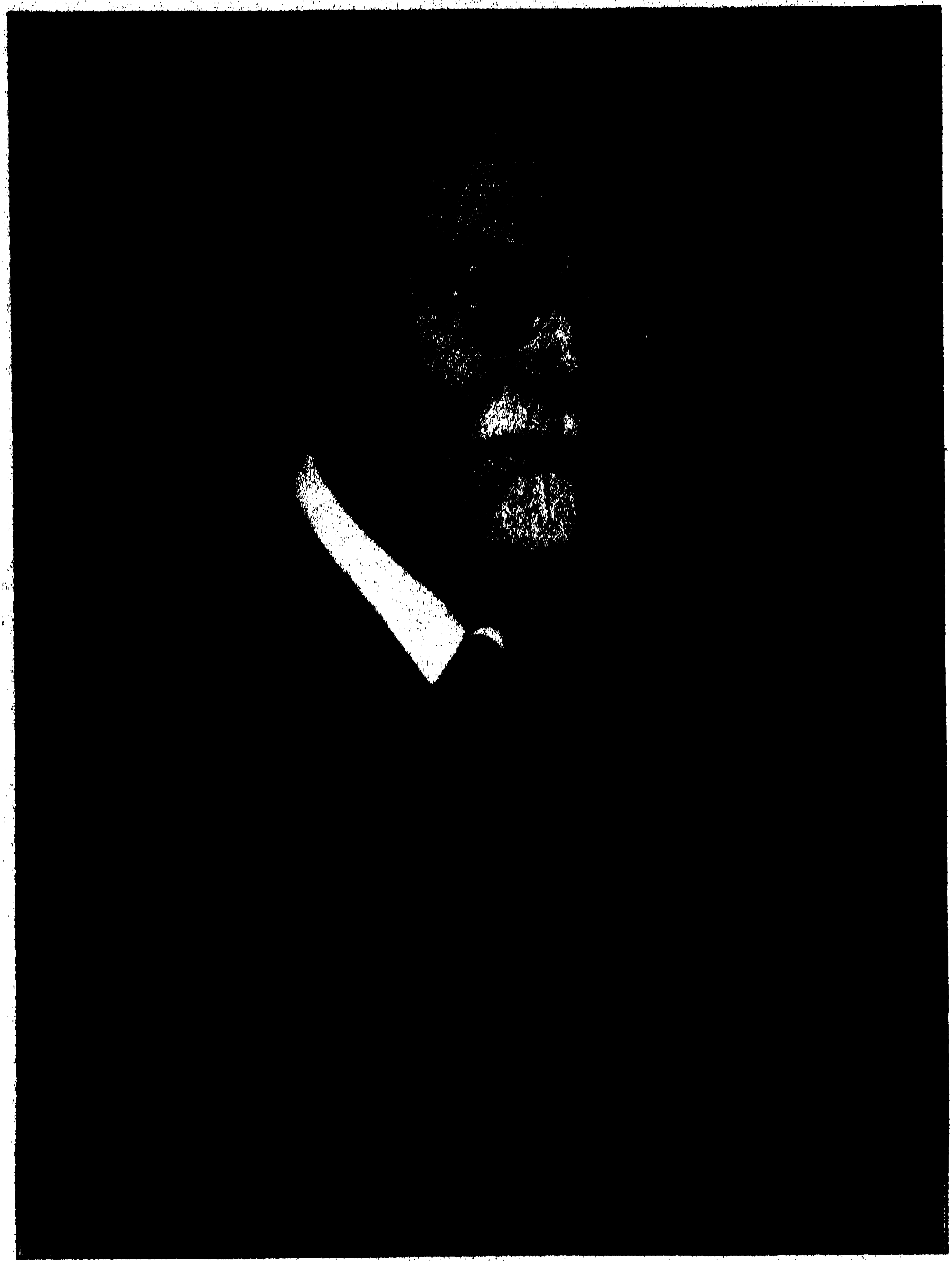
The use of this fish as a badge of dignity was revived by one of the Mogul emperors about the time of Queen Elizabeth and much later was conferred on General Gerard Lake, who won fame in India in the Mahratta War during the administration of the Marquess Wellesley. In 1803 he visited Shah Aulum (recall "Ullum" in the description of the insignia) at Delhi, from whom he received a high-sounding Persian title, which may be translated "the Victorious in War, the Savior of the State, and the Hero of the Land." Later General Lake was made Lord Lake and in 1807 was vested with the title of Viscount Lake of Delhi and Laswaree and to his paternal coat of arms was added the banded carp (Fig. 4) indicative of his Asiatic honors—probably the highest that could be given him.

A Fish with a Shell Neckpiece

Although strictly it does not belong here, yet possibly because it is *somewhat* allied to the matters presented above, and possibly because of its unusualness and interest, perhaps I may be forgiven for telling the short story of the fish with the shell neckpiece.

Early in May, 1930, Mr. C. M. Breder, Jr., of the New York Aquarium, discovered in one of the tanks a small ($1\frac{3}{4}$ inch) red-bellied dace (*Chrosomus erythrogaster*), adorned with a most curious shell ornament worn on the back. This is seen in Figs. 5 and 7, lateral and head-on views of fish and ornament. Knowing my interest in such matters, Mr. Breder told me about this fish, and on May 19 I visited the Aquarium and saw what is shown in these figures. These illustrations are reproduced from pencil sketches made for me by Mr. Breder. The ornament disappeared from the fish on May 30, after about a month's wear.

The explanation is a bit difficult. Mr. Breder's suggestion is shown in Fig. 6. Among the shells at the bottom of the tank, one must have become weakened by chemical action in the region of the heavy line. Some fish in nosing about put pressure on this small segment of shell and it fell out. The same or another fish happened to push its head into the opening and the shell got caught on the body of the fish, touching it at three points (the third is the dorsal fin). Here it held until chemical corrosion on the points touching the fish's body loosened the ornament and it fell off.



EDWARD LEAMINGTON NICHOLS

IN WHOSE DEATH, AT THE AGE OF EIGHTY-THREE YEARS, EXPERIMENTAL PHYSICS HAS LOST ONE OF ITS LEADERS. DR. NICHOLS WAS PROFESSOR OF PHYSICS AT CORNELL UNIVERSITY, IN RECENT YEARS AS EMERITUS, FOR FIFTY YEARS. HIS RESEARCH WAS MAINLY IN THE FIELD OF LIGHT AND COLOR. HE DID MUCH TO PROMOTE SCIENTIFIC RESEARCH AND ORGANIZATION, HAVING BEEN PRESIDENT OF THE AMERICAN PHYSICAL SOCIETY, THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND SIGMA XI.

THE PROGRESS OF SCIENCE

WORK LEADING TO THE AWARD OF THE NOBEL PRIZE IN PHYSICS

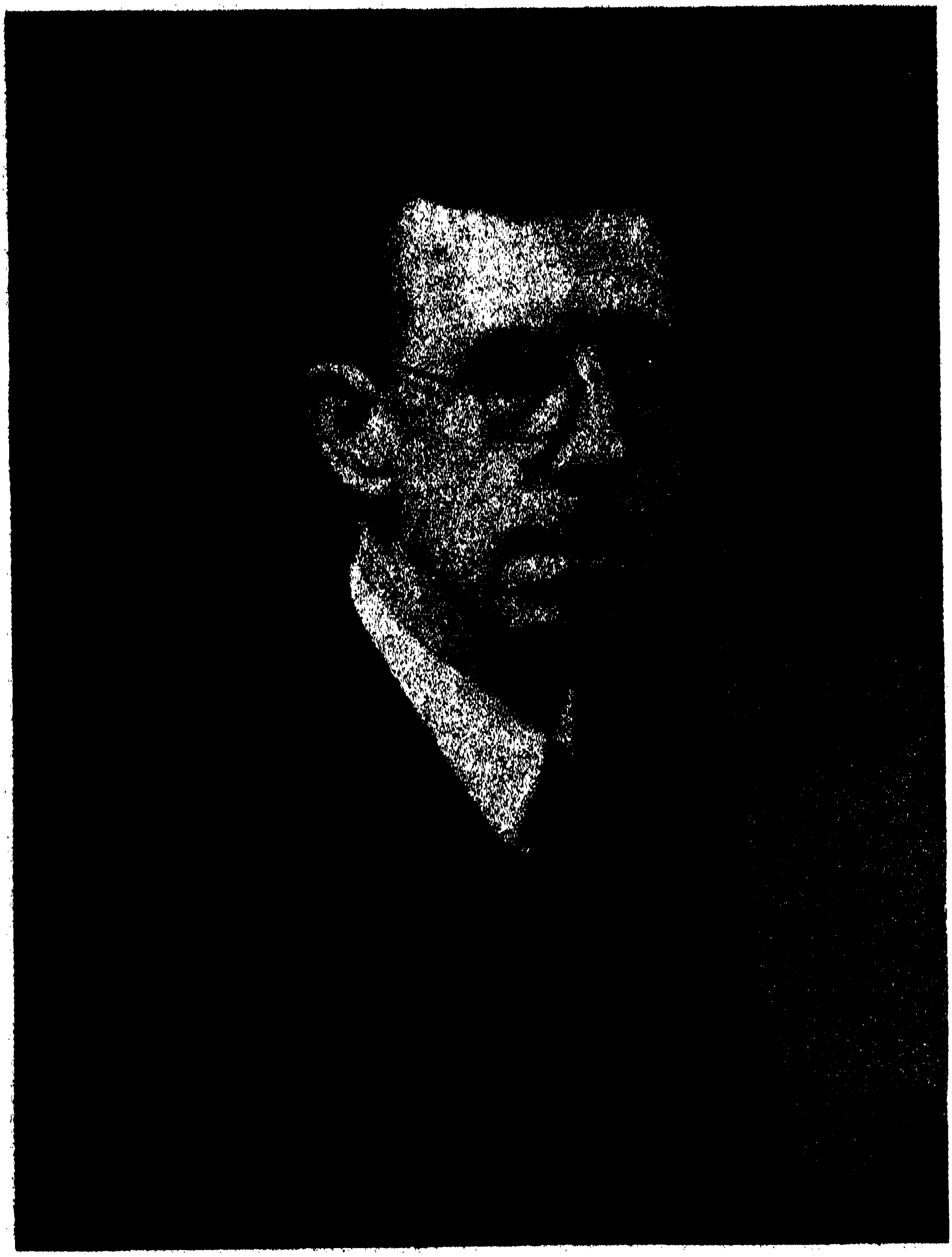
NOWADAYS when a physicist thinks of an atomic or a subatomic particle—be it an atom, an electron of either sign, a neutron, a proton, a corpuscle of light—he is likely to think of waves as well. He may, and often does, have only the vaguest sort of a notion or image of these waves; but he has a very definite value for their wave-length provided that he has fixed the momentum of the particle, while if he has a value for the energy of the particle he has an equally precise one for the frequency of the waves. Two by two these quantities are bound together by what may be called the "rules of correlation of particle and wave"—rules of the utmost simplicity, which are written thus,

$$p = h/\lambda, \qquad E = h\nu$$

when the customary symbols p and E are employed for the momentum and the energy of the particle, λ and ν for the wave-length and the frequency of the waves. Awareness of these interrelations, awareness of the coexistence of particles and waves connected by these equations, have been gradually growing and expanding ever since 1899, when Max Planck started the trend of thought which has culminated in these rules of correlation. Planck's rôle in the history of physics is well commemorated by the name of the universal constant denoted by h in these equations: it is Planck's constant. As Planck's name at the beginning, so the names of the Nobel laureates of 1937—C. J. Davisson and G. P. Thomson—stand at the climax of this great period of discovery: the period during which the association of waves and corpuscles, dimly and partially guessed at the start, was year after year progressively revealed as a universal principle.

During almost the whole of this twenty-eight-year period, the association was realized for light and for light alone; and during fifteen of those years it was only the second of the rules of correlation ($E = h\nu$) which was known. Any physicist who was educated in the last ten years before the war must surely remember the nervous and dubious way in which he was taught of the strange phenomena which had revived the long-buried corpuscular theory of light. These were phenomena in which only the energy of the corpuscles was apparent, and accordingly it was only the interrelation of E and ν which was grasped. It was Einstein who proclaimed most daringly the coexistence of corpuscles and waves; and it was also Einstein who in 1915 completed the correlation—completed it in so far as light, and light alone, was concerned—by discerning the other of the two rules. It frequently happens in physics that the first-to-be-discovered way to a new principle is also one of the hardest ways: and almost always it has so happened in the history which I am briefly retelling. There must be many a physicist to whom the equation $p = h/\lambda$ is already almost second nature, and who yet has never read Einstein's paper of 1915. It was the Compton effect which in 1922 made this interrelation intelligible to all.

Now that the correlation was successfully made for light, the extension to electricity and matter followed quickly. The first to suggest that the Rules of Correlation apply also to these was Louis de Broglie, in whose honor the associated waves are known as "de Broglie waves." Upon him followed Schroedinger, who applied to these waves very much the same sort of mathematical treatment as for decades has been familiar to the students of light-waves and sound-waves. By this method he assailed the great central problem of theoretical physics, the problem of the hydrogen atom. Bohr had already partially solved this prob-



DR. C. J. DAVISSON

MEMBER OF THE TECHNICAL STAFF OF THE BELL TELEPHONE LABORATORIES.

lem by imagining an electron revolving around a nucleus, and imposing certain prescriptions upon the orbits of this electron. Schroedinger now proceeded to show that if (for the sake of the argument) we dismiss temporarily from our minds the revolving electron and imagine instead its associated waves, then the stationary wave-patterns of these waves correspond to and determine the stationary states of the atom. This to this day is the accepted method of the theoretical physicist for investigating atoms and molecules, of all kinds and all degrees of complexity; and great have been its successes.

But was it not unsatisfactory to be obliged to prove these de Broglie waves by invoking so intricate and recondite a theory as that of the atom, while for light-waves there are so many and such beautiful experiments of interference and diffraction to make them obvious? It *was* unsatisfactory indeed; and we should still remain in that difficult situation, were it not for the experiments which

Davisson and Thomson were the first to perform. They *did* achieve obvious and spectacular diffraction of the waves associated with electrons, similar to the diffraction of light of corresponding wave-length. "Light of corresponding wave-length" signifies x-rays: electrons of convenient speeds are correlated, by the rule aforesaid, with waves as short as those of x-rays, while de Broglie waves of wave-lengths like those of visible light correspond to electrons so slow-moving that technical difficulties impede the experiments. They achieved this diffraction just as that of x-rays is achieved: by employing crystals as diffraction-gratings. The beam of free negative electricity, consisting of a stream of electrons of uniform speed associated with de Broglie waves, was projected against a single crystal in Davisson's experiment—against a very thin polycrystalline film

PROFESSOR GEORGE PAGET THOMSON

DEPARTMENT OF PHYSICS, IMPERIAL COLLEGE OF SCIENCE, UNIVERSITY OF LONDON. PROFESSOR THOMSON IS THE SON OF SIR J. J. THOMSON, HONORARY PROFESSOR OF PHYSICS, UNIVERSITY OF CAMBRIDGE, AND MASTER OF TRINITY COLLEGE.

KING GUSTAV OF SWEDEN

PRESENTING THE NOBEL PRIZE TO DR. DAVISSON. KING GUSTAV, WHO WILL BE EIGHTY-ONE YEARS OF AGE IN JUNE, IS KNOWN FOR HIS SKILL IN TENNIS TOURNAMENTS. LIKE HIS DISTANT COUSIN, KING CHRISTIAN OF DENMARK, AND OTHER MEMBERS OF THE BERNADOTTE FAMILY, HE IS VERY TALL, IN MANNERS AND APPEARANCE "EVERY INCH A KING."

of metal in Thomson's. Had it not been for the waves, the electrons would presumably have dispersed in every direction in a chaotic outrush as soon as they encountered the thickly set atoms of the crystals. The waves, however, were guided, by the regularity of the crystalline lattice, into each of a limited number of sharply defined directions according to the classical laws of diffraction; and they in their turn guided the electrons. Davisson and Thomson provided, for the waves associated with electrons, evidence as clear and striking as that which the world had long since received and accepted as proof for the waves of light. Also their measurements substantiated the rule of correlation $p = h/\lambda$ for the electrons and their waves. Also they initiated a new and ever-expanding field of research, the investigation of the structures of thin films by use of the diffraction of electrons: but this is another story.

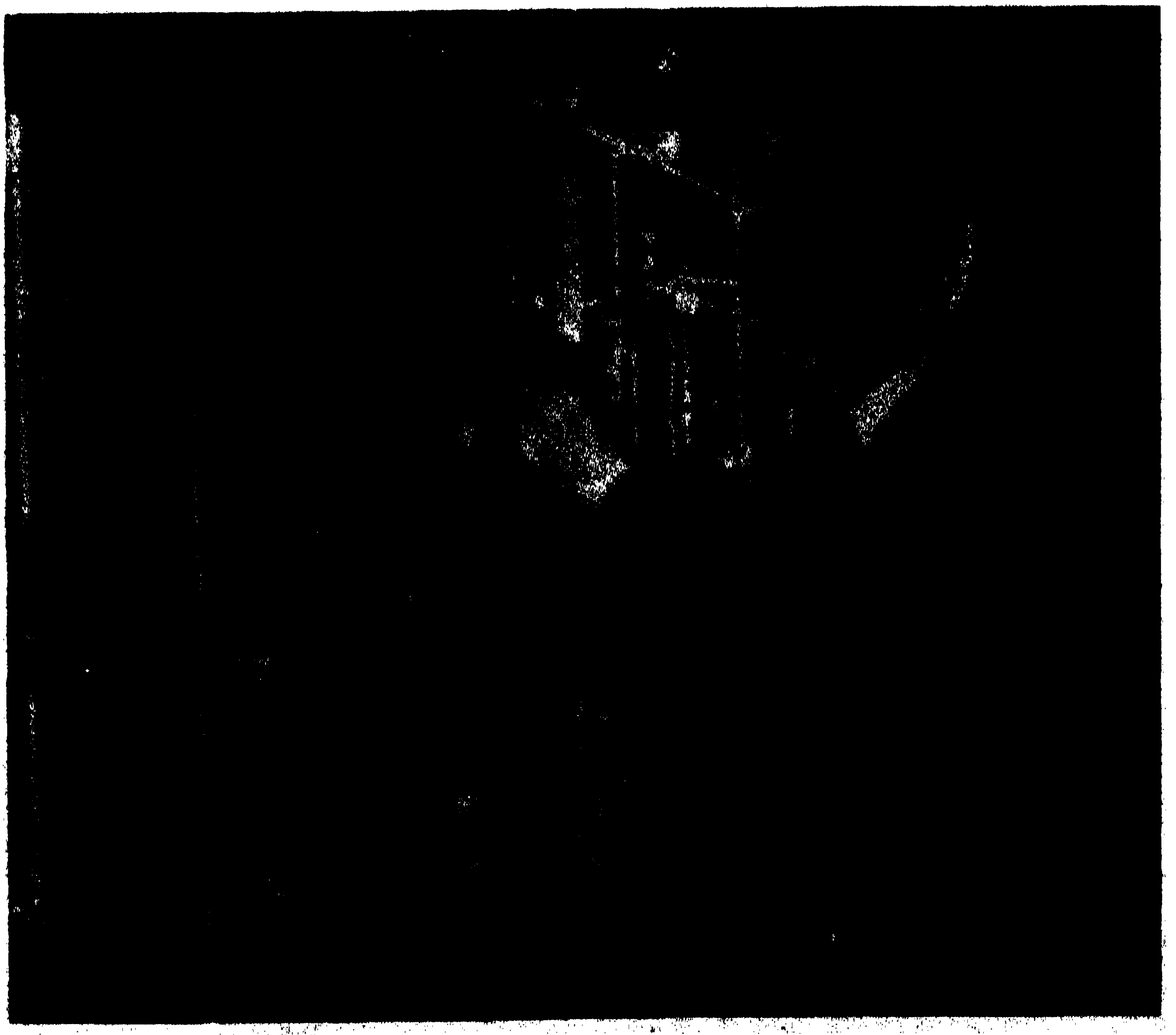
KARL K. DARROW

THE PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY

THE election of Professor Charles A. Kraus, director of chemical research at Brown University, as president of the American Chemical Society has been announced. As head of a group of some 20,000 chemists, Professor Kraus will take over the office on January 1, 1939, succeeding Professor Frank C. Whitmore, of the Pennsylvania State College.

Dr. Kraus, who has devoted his life to science and to its relationships with human welfare, will direct a broadened program of chemical research in the new laboratory recently erected at Brown University at a cost of $500,000 which will be opened next September.

Professor Kraus is best known in the world of industrial chemistry for a research which led directly to the commercial production of the "high test" or ethyl gasoline, familiar to every motorist. His investigations into anti-knock fuels were carried out in cooperation with one of the leading companies. He is also known for the development of the first method for making vacuum-tight seals between ordinary glass and fused quartz. He was last year awarded the Theodore William Richards Medal by the Northeastern Section of the American Chemical Society for his work on the theory of solutions, especially in connection with



PROFESSOR CHARLES A. KRAUS
PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

ammonia. In 1935 the Chicago Section of the society presented to him the Willard Gibbs Medal for his work in the same field. Two years earlier, the Nichols Medal of the New York Section of the American Chemical Society was awarded to him for his work on non-aqueous solutions. These investigations have demonstrated that certain metals are capable of forming solutions with liquid ammonia, which at high concentrations behave as metals. At low concentrations the solutions are salt-like and conduct electricity electrolytically. With his graduate students, Professor Kraus has so widened the horizon of knowledge of liquid ammonia solutions that to-day more is known about liquid ammonia than about any other solvent except water. He has also extended scientific knowledge of the field of metallo-organic compounds, particularly those of tin, germanium, silicon and boron. He has brought to light numerous new substances of scientific interest, including alloys that behave like salts and metallic compounds that contain carbon and hydrogen.

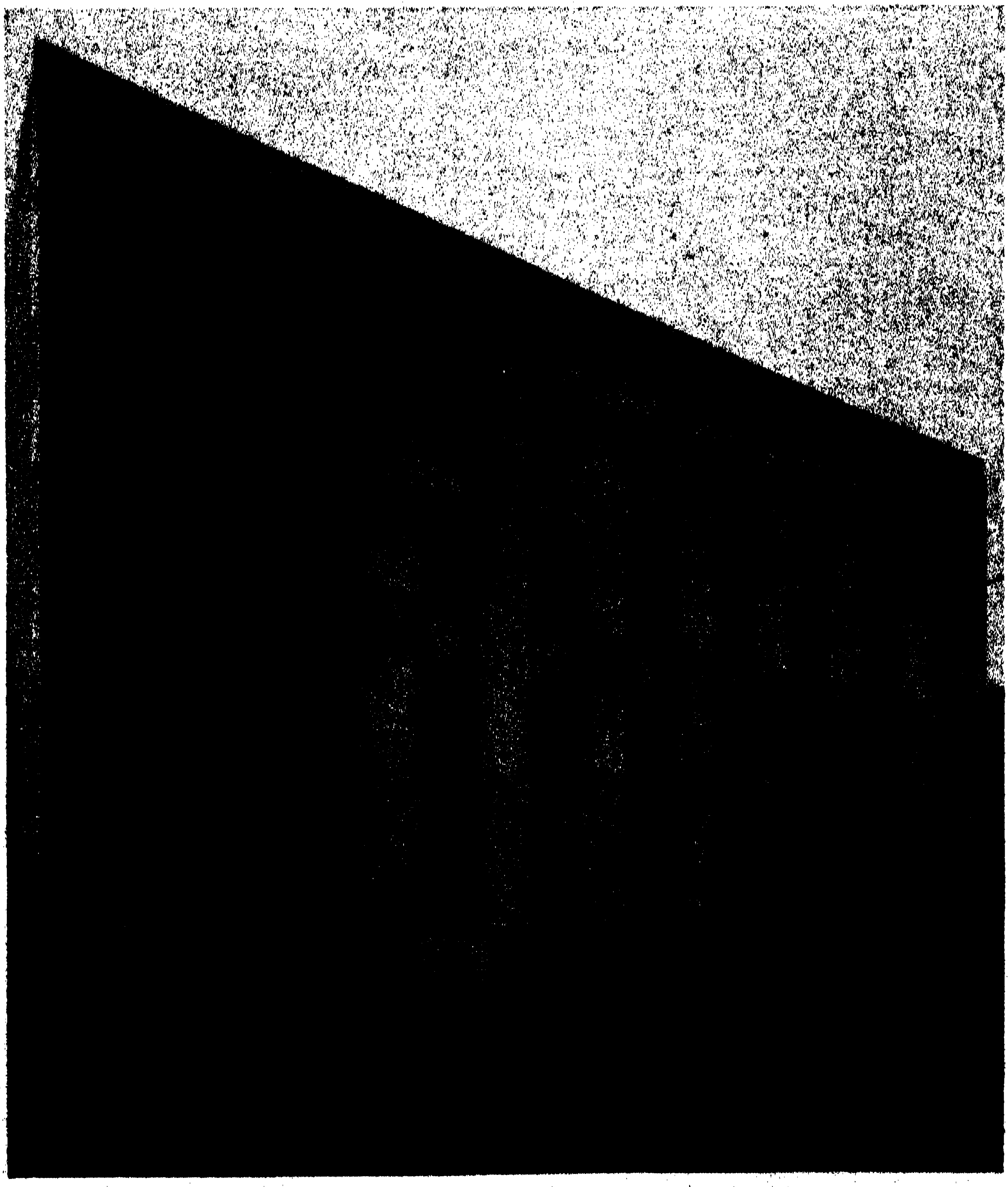
Dr. Kraus received the B.S. degree from the University of Kansas in 1898 and the degree of Ph.D. from the Massachusetts Institute of Technology in 1908. In the meanwhile he had been fellow of the Johns Hopkins University, instructor in the University of California and assistant in the Massachusetts Institute of Technology. He became professor of chemistry and director of the chemical laboratories at Clark University in 1914 and during the war directed research at the university for the Chemical Warfare Service, acted as consulting chemist for the Federal Bureau of Mines, and from 1922 until 1924 was in charge of the Fixed Nitrogen Research Laboratory. He first became associated with Brown University as a lecturer in 1923 and the following year was appointed professor of chemistry and director of chemical research.

THE NEW HEALTH CENTER BUILDING IN BROOKLYN

The new Red Hook-Gowanus Health and Teaching Center, erected at a cost of $250,000, at 250 Baltic Street, Brooklyn, the eighth city-built and Public Works Administration-financed health center building to be opened in New York City during 1937, was dedicated by the Health Department on November 30. The structure is the second unit in New York City's cooperative program with the five medical schools in the city for utilizing district health work as a training ground for medical students, Health Department personnel and other public health workers, in preventive medicine and public health administration.

The teaching program in the Red Hook-Gowanus district is conducted in cooperation with the Long Island College of Medicine, in close proximity to the new health center. The medical school's department of preventive medicine and community health, under the direction of Dr. Alfred E. Shipley, is housed in the building, which has facilities for maintaining a public health service for the community, with emphasis on preventive medicine and health education. Dr. Leopold Rohr is director of the center.

Quarters for the medical school are provided on the fourth floor. These include offices, a faculty room and laboratory and lecture and study rooms for students. Health Department personnel, including the district health officer, heads of clinics and supervising nurses, participates in the teaching program for medical students. The teaching of preventive medicine and community health under Dr. Shipley and his staff is begun in the first year and extended into the clinical years, in this way emphasizing the integration of the practice of preventive and curative measures. Social and medical practices



THE NEW RED HOOK–GOWANUS HEALTH AND TEACHING CENTER

for the control and prevention of infectious diseases are considered, with particular reference to the physician's rôle in applying these measures in his community. The instruction culminates with a four-week clerkship for senior medical students at the health center. Approximately ninety fourth-year students of the Long Island College of Medicine are divided into groups of ten for the clerkship course. Thus the senior medical students serve an apprenticeship in the tuberculosis, venereal disease and child hygiene clinics; observe dental hygiene procedures and attend conferences of local physicians, cooperating agencies

and civic and medical groups, for a broader understanding of community health problems.

The Red Hook-Gowanus Health and Teaching Center is of white brick and stone construction, with basement and four stories. The building occupies a site fronting 75 feet on the south side of Baltic Street, between Court and Clinton Streets, and has a depth of 100 feet. The main entrance on Baltic Street leads into a spacious lobby. On the first floor are the maternity and child health and the dental and social hygiene services and conference and waiting rooms. On the second floor are the tuberculosis and eye services, quarters for the establishment of a parasitology clinic, the district office of the Brooklyn Bureau of Charities and quarters for the United Jewish Aid Society. On the third floor are the district health officer and administrative staff, Department of Health and Brooklyn visiting nurses, health education staff and a conference room for physicians of the district. The fourth floor houses the Long Island College of Medicine and the district office of the Brooklyn Bureau of Charities. The basement of the building includes an auditorium, exhibit rooms, a nutrition department, a staff kitchen and lunchroom, a staff emergency room and boiler and storage rooms.

New York City's district health program provides for the organization of thirty health center districts by 1945 or one administrative unit to serve each 250,000 population area of the city's approximately 7,500,000 people. Since last June, new health center buildings have been opened in the East Harlem, Central Harlem and Lower West Side districts in Manhattan; in the Mott Haven section of the Bronx; in St. George, Staten Island; in Astoria-Long Island City, Queens, and in the Williamsburg-Greenpoint and Red Hook-Gowanus districts, Brooklyn. Of these, the Red Hook-Gowanus and the East Harlem buildings, the latter in conjunction with New York Medical College and Flower Hospital, are combined health and teaching centers. A third unit in the health and teaching program is being built and will be opened this year. This is the Kips Bay-Yorkville Health and Teaching Center at 411 East 69th Street, Manhattan, which will be operated in conjunction with the New York Hospital-Cornell University Medical College. Building plans are under way for the Lower East Side Health and Teaching Center, East 25th Street and First Avenue, in cooperation with the New York University College of Medicine, and the Washington Heights Health and Teaching Center, West 168th Street and Broadway, in cooperation with the College of Physicians and Surgeons, Columbia University.

Although the new health and teaching center buildings will be located in only five of the city's thirty health districts, the benefits obviously will be city-wide. The medical colleges will be able under this program to offer their students courses in public health practice and preventive medicine, which will be closer to the realities than ever before. Aside from the gain which this training will record in public health administration, there should be immeasurable enrichment in the field of private medical practice. Medical students who have had the training which the health and teaching centers provide and who will ultimately go into private practice, will be fortified with more extensive experience in preventive medicine for use in their daily work than has heretofore been the case.

The health and teaching program which New York City is launching is the product of the best thought of leaders in the fields of medicine and public health administration. Development of the program has had the active support and

leadership of Mayor Fiorello H. LaGuardia, and realization of the undertaking would not have been possible except for the understanding, effort and assistance of the deans and other officials of the cooperating medical schools. This is another step forward for the New York City Department of Health, as well as for the medical profession, in their mutual efforts to serve the community.

JOHN L. RICE,
Commissioner of Health

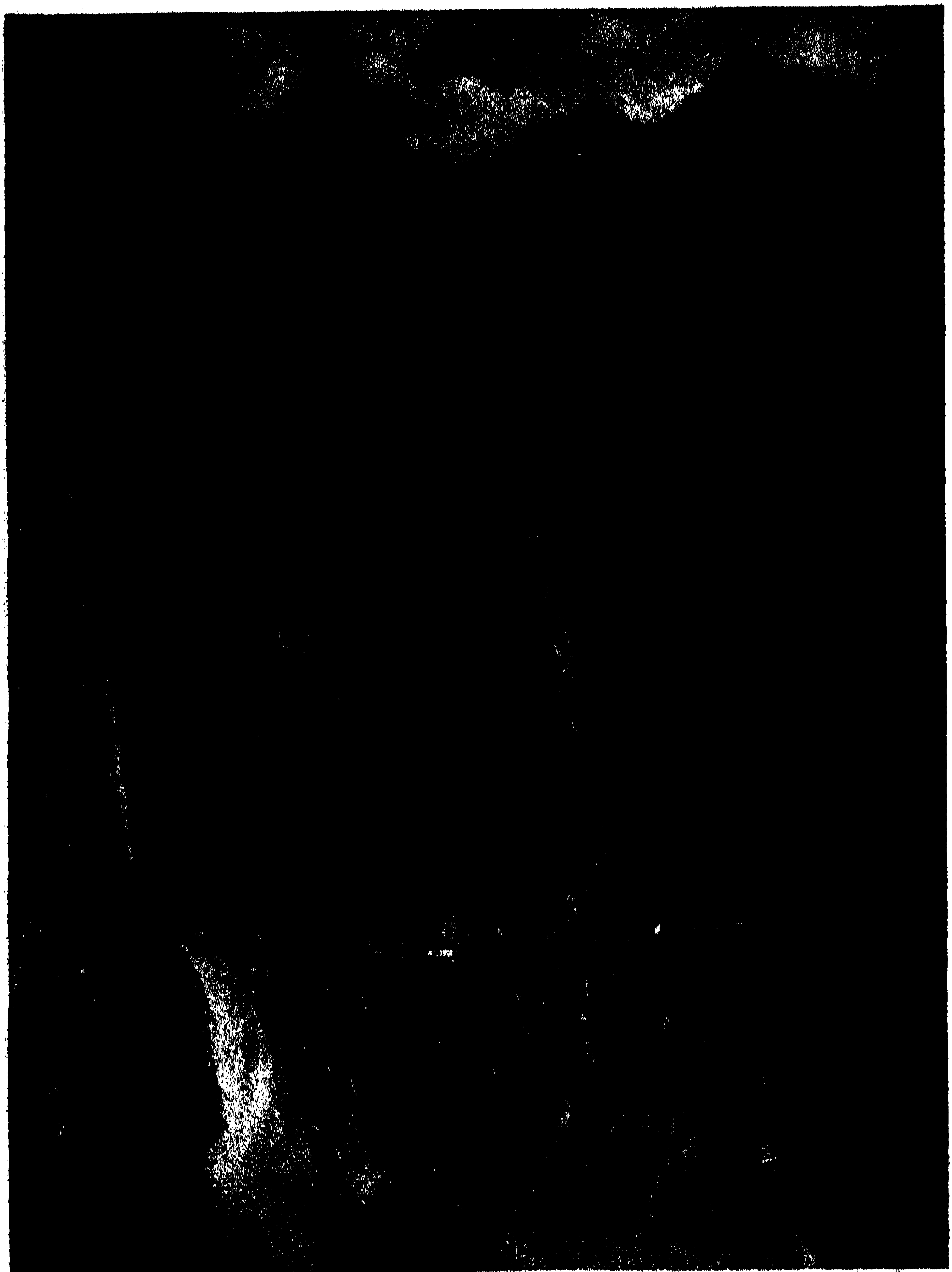
AVALANCHES IN THE SWISS ALPS

To the man in the street an avalanche is an avalanche. Even to the dictionary it is simply "a large snow slide." However, there are different kinds of avalanches, and they vary according to the weather conditions that produce them. They are generally classified into ground and dust avalanches.

—*Photo by Erika Nikles*

A WETTERHORN AVALANCHE

WHICH DESCENDED RECENTLY NEAR GRINDELWALD IN THE BERNESE OBERLAND, SWITZERLAND.



—Photo by G. Schneiter

THE LÖTSCHBERG RAILWAY

IN SWITZERLAND, WHICH CONNECTS THE BERNESE OBERLAND WITH THE SIMPLON ROUTE IN THE VALAIS, FEATURES NUMEROUS PROTECTIVE AVALANCHE GALLERIES ON ITS SOUTHERN SIDE.

—*Photo by Marga Steinmann*

A JUNGFRAU AVALANCHE

IN THE BERNESE OBERLAND, SWITZERLAND. ONLY ON RARE OCCASIONS DO PHOTOGRAPHERS HAPPEN TO BE ON HAND WHEN THIS CATARACT OF POWDERY SNOW MAKES ITS SWIFT DESCENT FROM THE MOUNTAIN.

Of the ground avalanches there are some that affect the actual surface of the land over which they travel but slightly; others, however, dig deep into it, and furrow it and maul it like gigantic ploughs. Both kinds will sweep away the rocks, trees and houses that happen to be in their path. When the so-called "Black" avalanche has finished its work of devastation it is an ugly-looking accumulation of dirt, tree-trunks and mud-colored snow. The "White" variety, as its name implies, though equally destructive to hillside, forest and mountain chalet, comes to its rest with an untarnished, glittering surface.

Dust avalanches are the most dreaded, for while the ground avalanches fall according to well-known rules, at specific times of the year, the dust avalanches are erratic in their movements. Dust avalanches consist of dry, powdery snow which is susceptible to the slightest vibration. Loosened from the vertical face of the cliffs to which it has been clinging, it begins to run down like grains of sand, growing as it falls, by drawing down with it other beds of snow. It is like a snowy waterfall, bursting out suddenly from the mountain. Swiftly it gathers speed and with ever-increasing power and a deafening roar, caused by the tornado-like wind which always accompanies an avalanche, it uproots trees, crushes chalets and whatever happens to be in its course. At the end of its path of destruction it covers the ground with a bed of snow from thirty to fifty feet deep.

Avalanches are a regular feature in certain alpine districts when the warm

THE SWISS FEDERAL RAILROADS
HAVE CONSTRUCTED VERITABLE FORTIFICATIONS ALONG THE ST. GOTHARD LINE NEAR FLUELEN AT THE SOUTHERN EXTREMITY OF THE LAKE OF LUCERNE.

breath of spring softens and loosens some of the old frozen snow. These so-called "melting avalanches" invariably follow certain tracks which are strongly embanked like the course of a river with branches and timber. In order to be out of the avalanche path, the human dwellings in such sections are generally huddled closely together, and alpine highways and railroads are carefully protected by scientifically constructed galleries.

While the average visitor will probably never experience the thrill of observing an avalanche in its descent from a near-by point of vantage, alpine climbers are more likely to encounter this fortunately not frequent peril. Long experience and careful observation of this phenomenon in nature have enabled the Swiss people to meet it with adequate measures of precaution and defense.

MARIE WIDMER

THE SCIENTIFIC MONTHLY

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LIFE IN THE SEA

By Dr. R. E. COKER

PROFESSOR OF ZOOLOGY AND CHAIRMAN OF THE DIVISION OF THE NATURAL SCIENCES, UNIVERSITY OF NORTH CAROLINA

And know, moreover, that all that is on the land, in comparison with what is in the sea, is a very small matter. (Jullanár to King Sháh Zemán).

CONDITIONS OF LIFE IN THE SEA[1]

Size and Continuity

Features of the seas that first command attention are their sizes and their continuity. The combined area of the oceans is more than twice that of the lands and their mean depth (3,500 m. or 11,500 ft.) more than four times the mean elevation of the land (700 m. or 2,300 ft.); hence, if all the land were submerged in the sea, such a cataclysm would, after all, cause the displacement of only a relatively small volume of the water. The surface of the earth might indeed be said to be covered with a continuous layer of water from which emerge larger or smaller parts of the solid crust in the form of isolated continents and islands. The isolation of the bodies of land contrasts, therefore, with the continuity of the bodies of sea water, and, if we turn attention to bodies of fresh water in the form of lakes and streams, we find still greater degrees of isolation. Just as the lands are separated from one another by the much larger oceans, so the lakes and ponds and rivers are separated from each other by the greater areas of land. Within a continent or an island there is continuity of land, but continuity of fresh waters is limited to those of a single system or basin, several or many of which are found on any given land mass.

1 This paper has developed somewhat gradually in connection with the author's teaching of classes in hydrobiology. Kind friends who have read the manuscript at various stages have suggested its publication. It requires some temerity even to approach the large task of compressing into a small space a comprehensive but necessarily incomplete picture of the great complex of environmental conditions surrounding and governing the lives of individual plants and animals in the sea and controlling the evolution of life in the mother waters. The author has simply felt that this ought to be done—not for the benefit of oceanographers, but rather for all who are interested in the conditions of organic life as it is lived in the greater part of the biosphere. Since the readers, if any, are terrestrial, we have made it a point frequently to emphasize the contrast between the surroundings and problems of organisms in the sea as compared with those of organisms living on land or in fresh water. Obviously the paper is a compilation. We may have erred in giving credit in some places when we could not give it in all; therefore, to any one who may find his ideas or information borrowed without express credit we extend a sincere apology in advance. We are indebted to Dr. W. C. Allee, University of Chicago, and Messrs. H. R. Seiwell and Columbus Iselin, of the Woods Hole Oceanographic Institute, for reading the manuscript and offering certain suggestions; but for any shortcomings in the selection or presentation of material the author must accept entire responsibility. The figures adapted from Murray and Hjort, "The Depths of the Ocean," are used by permission of The Macmillan Company, Publishers.

The contrasting aspects of continuity and isolation have marked biological significance. For an animal or a plant the several systems of fresh water, even though comparatively close together geographically, may be widely separated the one from the other by almost insuperable barriers of land, salt water or atmosphere. In the State of New York, for example, the passage from Lake Chautauqua of the Mississippi drainage to Lake Seneca of the Middle Atlantic drainage involves a journey of about 125 miles by land or air but one of several thousand miles by water, fresh and salt—down the Mississippi, across the Gulf of Mexico, up the Atlantic Ocean and the Susquehanna River. The journey from Lake Chautauqua to Lake Erie, only about 8 miles by land or air, once represented (before the construction of the Chicago drainage canal) a path by water even longer than that to Seneca Lake, or nearly a fourth of the distance around the earth at the equator. Notwithstanding the continuity of the oceans, there still exist some effective barriers to the free migration of animals and plants—barriers of temperature, of depth and pressure and of character of bottom or of food supply. Perhaps there are also less prominent barriers of salinity, but chemical barriers in the seas are based on degree of concentration rather than on different combinations of mineral substances such as distinguish different fresh waters or soils. The barriers that exist within the ocean are, then, of the sort that we would call "intangible," as contrasted with the more prominent and abrupt barriers that may bar the free movement of fresh-water or terrestrial animals and plants.

The oceans are not alike, of course. It is not only that Arctic and Antarctic waters are extremely different in temperature and dissolved gases from tropical waters of Atlantic, Pacific and Indian Oceans, but that the several oceans are different in corresponding latitudes. Geologic events and the distribution of continents and islands, as they influence the movements of currents, must have profound effects on the physical and biological conditions in the several oceans and in their various parts. The coastal contacts of Atlantic and Pacific are markedly different, as a glance at the map will show. "The Pacific is bounded everywhere by steep slopes, rising abruptly from profound ocean depths to lofty lands crowned with mountain ranges parallel to its shores and surrounding its whole area. . . ." "'This mountain ring,' as Charles Lapworth said, 'is ablaze with volcanoes and creeping with earthquakes, testifying that it has been recently formed and is still unfinished.'" (Watts, 1935). Almost everywhere the continents present a very different sort of front to the Atlantic, with, generally, a broader continental slope. Watts has interestingly suggested that the Atlantic has been formed by a splitting of a greater continent, and the slow drifting apart of the Americas on the one side and Europe and Africa on the other—a highly theoretical assumption, of course.

Without going into details, even if the space or our capacity permitted, it is adequate for our present purpose to give warning, as it were, that the conditions of life and the composition of the organic communities are very different in the several oceans and, in consequence of this and other conditions, the constitution of organic deposits on the bottom are distinctive of different regions. The Atlantic and the Pacific, for example, are different oceans, biologically as well as geographically. Assuming, however, that an animal was broadly tolerant of temperature conditions, as some of the whales may be, it could wander at will over the greater part of the surface of the globe. Assuming, again, that an animal were capable of adapting itself to great extremes of pressure and to foregoing the

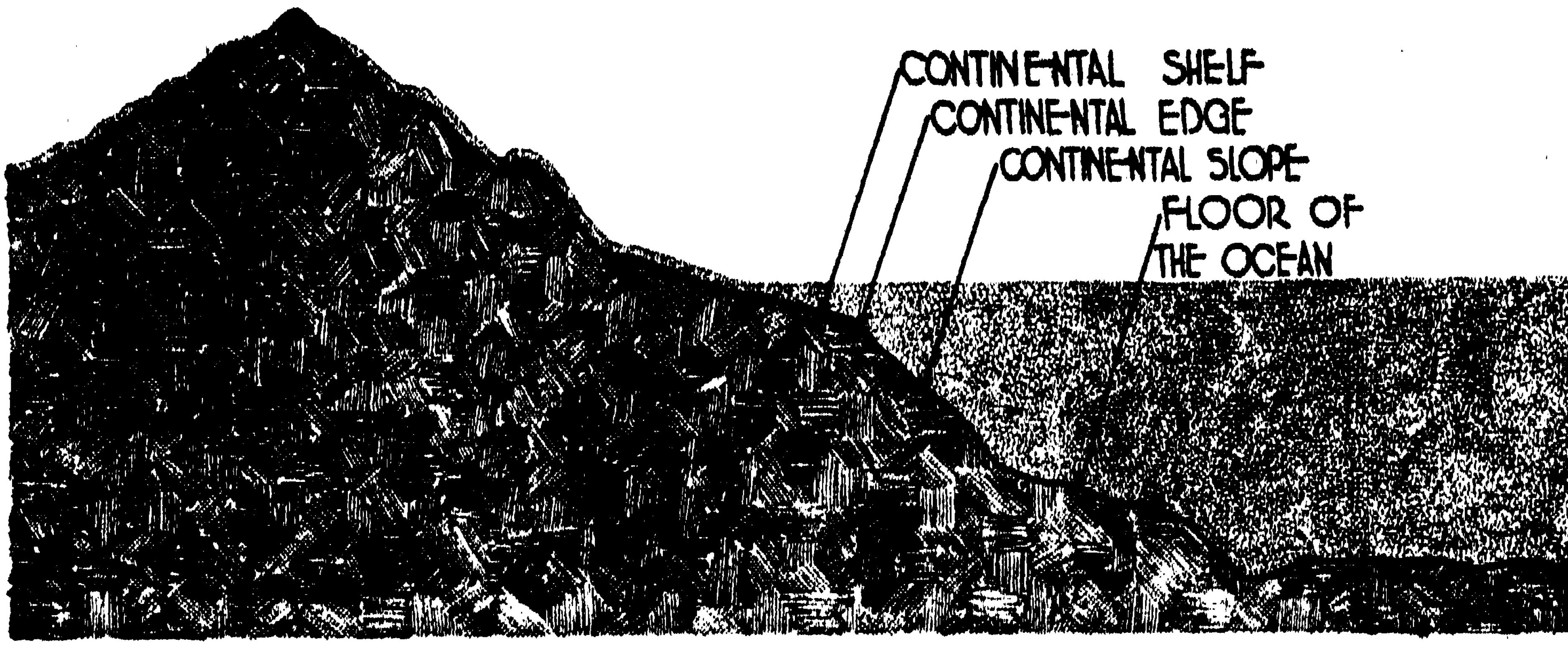
presence of sunlight, as may be the case with some copepods and other invertebrates, it could find practically constant conditions of temperature in travel from the Arctic across the equator to the Antarctic in either ocean. We need not, however, overstrain the imagination by assuming that any invertebrate animal could accomplish such a journey in its lifetime.

The distinctiveness of different regions of the sea, whether viewed horizontally or vertically, is well reflected in the fact that knowledge of currents and drifts is generally found not so much by the use of current meters as by study of the salinities, temperatures, dissolved gas contents or plankton. Whence comes the water of a particular place and time is often discoverable by chemical and biological analysis.

Depth and Topography

In respect to depth and topography the greater part of the sea is below two thousand fathoms, or 4,000 m., roughly speaking, but only a very small part, some 6 per cent., is below three thousand fathoms (about 3½ miles, or some 6,000 m.). Areas of greater depth than three thousand fathoms are known as "deeps." There is no great difference between the greatest height of the land (Mt. Everest, 29,002 ft.) and the greatest sounded depth of the sea (32,049 ft. or about six standard miles, in the Swire Deep off Mindanao in the Philippines). The largest and one of the deepest is Tuscarora Deep, a little east of Japan; in all at least fifty-seven deeps have been mapped. The bottom of the sea lying between two and three thousand fathoms, is generally an undulating plain with slopes that are usually, but not invariably, gentle. Some of the deeps have high cone-like elevations rising from their centers, with slopes of about 35°—comparable in inclination to a steep mountain side; these, with narrow tops that may be only some fifty meters below the surface of the ocean, are thought to represent submarine volcanic peaks. Proceeding from the shores of the continents toward the central parts of the

DISTRIBUTION OF THE "DEEPS"
INDICATED BY STIPPLING, OR AREAS EXCEEDING 3,000 FATHOMS IN DEPTH.
(AFTER MURRAY AND HJORT).



SCHEMATIC REPRESENTATION OF THE DISPARITY OF THE RESPECTIVE DEPTHS OF THE BIOSPHERE ON LAND AND IN THE SEA

HABITABLE REGIONS (THE BIOSPHERE) INDICATED BY STIPPLING. THE SCALE IS UNAVOIDABLY MISLEADING, SINCE THE STIPPLED AREA OVER LAND REPRESENTS A ZONE WITH DEPTH OF THE ORDER OF 30 METERS, WHILE THE SEA HAS A MEAN DEPTH OF SOME 4,000 METERS. SOME PROMINENT TOPOGRAPHIC FEATURES ARE ALSO SHOWN.

oceans there are commonly distinguishable, first, the *Continental Shelf,* with generally very gentle inclination but with many deep gorges and extending for a greater or less distance to the *Continental Edge* at about one hundred fathoms, and beyond this the much steeper *Continental Slope,* notched by the mouths of the gorges and leading down to the *Floor* of the ocean. On some coasts the Continental Shelf is wanting, as on the western coast of Peru, where the steep slope from the high peaks of the Andes continues almost unbrokenly down to the floor of the ocean below 20,000 ft., giving a continuous incline from peak to deep of some 40,000 ft.

Now, although there is relatively little difference between the greatest height of land and the greatest depth of the sea, there is a vast difference between the thickness of the zones of life on land and in the ocean, respectively. Terrestrial life everywhere occupies a very thin stratum that follows roughly the contours of the land, except at the greatest elevations, while oceanic life extends throughout the space from the surface of the ocean to the bottom, however deep it may be. The thickness of the stratum of life on land, which may roughly be said to extend from the tops of the crowns of the trees to the greatest depths to which their roots penetrate, will not ordinarily exceed 100 ft. or some 30 meters, and the mean thickness would certainly be much less; but if, with some exaggeration, we assume this to be the mean and take the mean depth of the habitable regions of the sea as about 12,000 ft. (about 4,000 meters), and if we remember that the area of the sea is more than twice the area of the land, we find the volume of space available for organic life in the ocean to be some 300 times the space available over the continents and islands. This a very rough sort of calculation, but it indicates at least the order of relative magnitude of the terrestrial and the oceanic communities as a whole.

Interrelation of Sea and Land

Not only are the continents and islands completely surrounded by the continuous sea, but almost all lands everywhere, as a result of weathering processes, are being worn down and washed or blown into the sea. It is estimated that nearly 3 billion metric tons of material from the land is annually being dumped into the sea. In-

deed were there no compensating returns to the land, a few geologic ages might have sufficed to cause the complete disappearance of all dry land. There have been, however, and there must always be such compensating movements, so long as the equilibrium of the crust of the earth is maintained by the gradual elevation, in continental regions, at least, of great areas of sea bottom to become dry land. Enormous terrestrial areas, even the very tops of some of our mountains, are known by their geologic formation and fossils to have been former sea bottoms, to represent, indeed, the repayment of long-term loans from land to sea.

In other ways than through geologic upheavals does the sea regularly contribute to the land. The interrelations are too complex to be analyzed briefly. It may only be suggested that the source of our rain and snow, of the rivers, lakes, springs and ground-waters everywhere is primarily the surface of the sea, where the heat energy of the sun enables the atmosphere to pick up by evaporation the topmost layers of water that may be dropped later upon mountain or plain. Then, too, the climates on land are regulated from the sea in various ways. The winds from the sea are well-known tempering influences, but it is not so generally understood that the great amount of heat energy absorbed by evaporation of the sea water is to a notable extent released by the precipitation that occurs when the warm water-laden breezes are cooled over the land. It is hardly relevant to our purpose to recall that the water powers that operate our lights and engines are giving us merely the energy of the sun that was stored through evaporation, and chiefly at the surface of the sea. In comparison with these contributions from sea to land, the gift to man, bird and other terrestrial animals of a few billion pounds of food and salt seems relatively insignificant, however important and perhaps absolutely essential these materials are to mankind.

THE "CARNEGIE" UNDER SAIL

Chemicals in Solution

Since the sea is the great catch basin for everything that leaches or is washed from the land, as well as for materials that drift in through the atmosphere, and from inter-planetary space, obviously it must be a great chemical potpourri. Doubtless the oceans have in solution every one of the chemical elements, but many of them occur in such slight traces that they can not be detected by ordinary methods of chemical analysis. Indeed there are some elements that, so far, have never been detected in the water but which, nevertheless, are found in marine organisms.[2] Still others are found in animal or plant in greater degrees of concentration than they occur in the water. In separating from the water some of the rarer elements, the protoplasm of the animal or plant is more effective than the most expert chemist. Only a limited number of the elements in solution have presently known biological significance, but some of these, such as iodine, an important component of some seaweeds, and copper, will show only as traces in the reports of chemical analyses. The accompanying Table I reproduces a rather

TABLE I

Analysis of Sea Water*

		gms.	*per cent.*
Sodium chloride	$NaCl$	27.213	77.76
Magnesium chloride	$MgCl_2$	3.807	10.88
Magnesium sulphate	$MgSO_4$	1.658	4.74
Calcium sulphate	$CaSO_4$	1.260	3.60
Potassium sulphate	K_2SO_4	0.863	2.46
Calcium carbonate	$CaCO_3$	0.123	0.34
Magnesium bromide	$MgBr_2$	0.076	0.22
Total		**35.000**	**100.00**

* From Helland-Hansen in Murray and Hjort, after Dittmar in Challenger Reports.

old-fashioned report of the more abundant substances revealed by analysis, but it must not be understood that the materials occur in just the combinations indicated, for the salts occur in sea water in ionized form and consequently are susceptible of diverse and changing combinations. Sodium, for example, may occur as the ion Na, or in combination with other ions as sodium chloride, sodium carbonate, sodium sulfate and sodium bromide.

The chemical composition of the sea water varies from about 31 to 37.5 parts of mineral salts per thousand of water, depending on evaporation and on admixture of fresh water by rivers and icebergs, but the relative proportions of the several salts is virtually constant. In the words of Bigelow (1931, p. 110): "Whether the sample be taken in the Atlantic, in the Pacific, or in the Indian Ocean, in high latitudes or in low, the total solutes are found to be about 54 per cent. chlorine; about 31 per cent. sodium; about 4 per cent. magnesium; about 1 per cent. potassium; 1 per cent. calcium; and about 0.2 per cent. bromine, with about 8 per cent. of sulfate radicals, about 0.2 per cent. of carbonate radicals. And this uniformity in the relative proportions of the commoner constituents is now so well established that it is customary . . . in practice to employ the concentration of one group of its salts as a dependable index to the total saltness. The variety of conditions and the vast areas throughout which such uniformity prevails makes this one of the outstanding phenomena of geochemistry." It may be added that there is as yet no adequate explanation for the great disproportion in which chlorine and sodium occur in the sea, as compared with other chemical substances currently contributed by the rivers. The region of greatest concentration in the ocean proper is the Sargasso Sea (37.5), that enormous central area of the great North Atlantic eddy, encircled by drifting waters, but itself marked by profound stillness and extreme remoteness from continental influences. Partially enclosed regions of especially high rate of evaporation may have 40 parts per 1,000,

[2] Vanadium in the blood of Ascidians and Holothurians, cobalt in lobsters and mussels, nickel in mollusks and lead in the ash of various marine organisms (Bigelow, 1931, pp. 109–110).

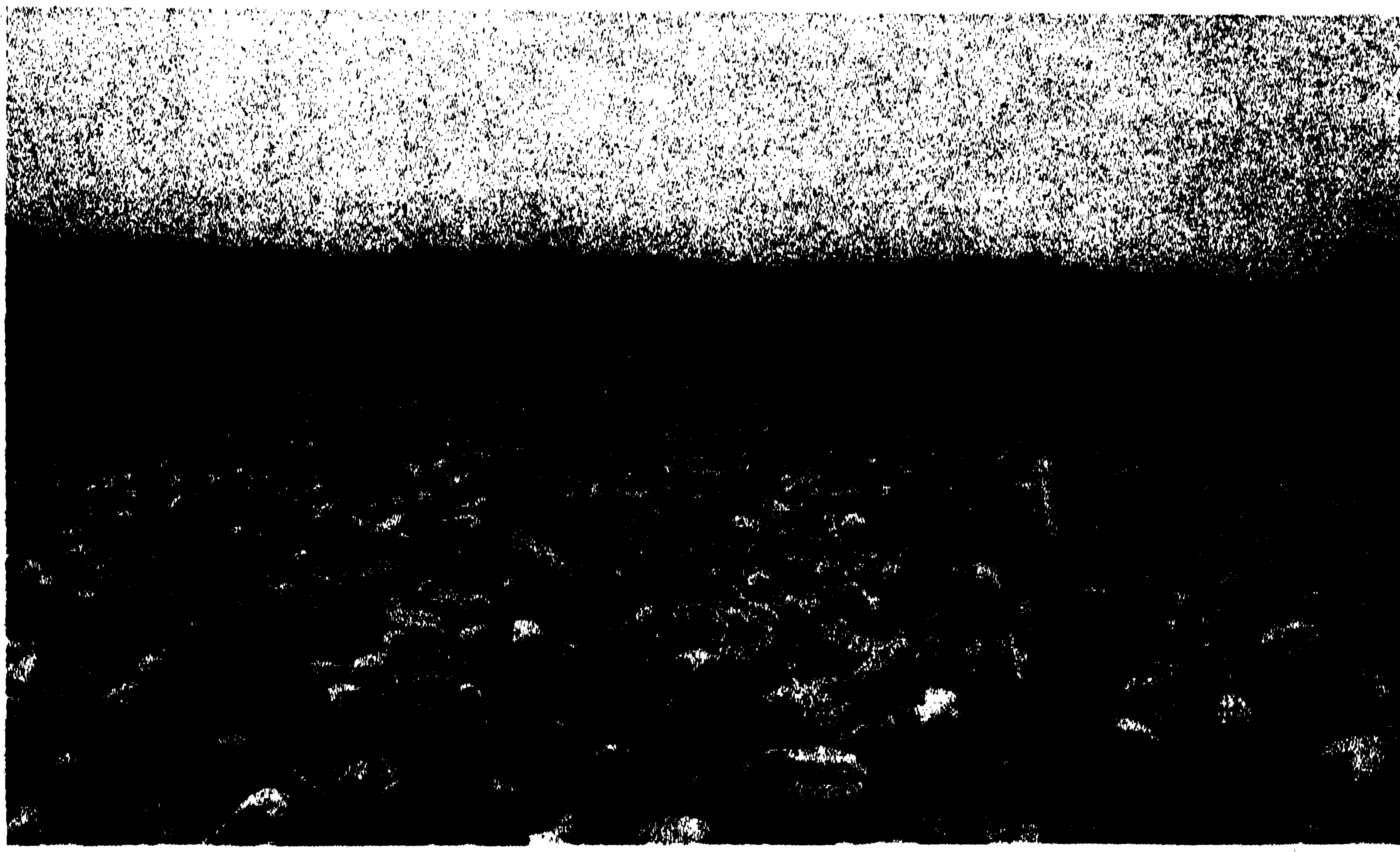


Photo by the author.

IN REGIONS OF UPWELLING

THE NUTRITIVE MATERIAL BROUGHT TO THE SURFACE PROMOTES A LUXURIANT DEVELOPMENT OF MICROSCOPIC PLANTS AND ANIMALS (THE PLANKTON), WHICH MAKES POSSIBLE A DENSE POPULATION OF SMALL FISH AND CRUSTACEA, AND THESE, IN TURN, SUPPORT GREAT NUMBERS OF BIRDS. PELICANS ON THE LOBOS DE AFUERA ISLANDS IN COLD WATERS NEAR THE EQUATOR OFF THE WEST COAST OF PERU.

as in the Persian Gulf, or 46.5 per cent. as in the Red Sea (Hesse), while the Baltic Sea, comparatively isolated as it is, from the open oceans, and receiving heavy contributions of fresh water, may have a salt concentration of less than 10 parts per 1,000.

The comparative uniformity in relative proportions of the dissolved materials in off-shore water may easily be over-emphasized. Substances in solution become directly or indirectly the foods of the organisms that live in the waters, and the abundance of the plants that chiefly appropriate them is very variable with the season. It may well be, then, that the materials that occur in minimal quantities relative to the demand are at times entirely removed from solution, so much so as to place a limit to the development of the organisms that require such substances. Nitrogenous compounds, phosphorus and silica, particularly, are found sometimes to become so depleted as to check the growth of plankton plants. Then some of the dying plants may sink into the deeper layers of water, there to become decomposed and dissolved, yielding up the chemical materials in a region where for lack of light they can not again be immediately utilized. Consequently the plant nutrients tend to become accumulated in the deeper strata while superficial waters become depleted.[3] As Krogh says:

> If no mixing took place the depletion would go on to exhaustion and life would die out except along the coasts, but in certain areas, mainly at fairly high latitudes, but also for

[3] Another phase of the one-directional flow of some of the materials necessary to organic life is suggested by the following comment of Bigelow (1931, pp. 31–32):—"with silica contributed by the rivers to the sea, and with no return loss either to the atmosphere or to the land (except in regions of elevation), it seems that the silica of the earth is now tending to accumulate on the sea floor."

Photo by Coit Coker.

THE WOODS HOLE OCEANOGRAPHIC INSTITUTION AND ITS SHIP, THE "ATLANTIS"

DESIGNED ESPECIALLY FOR EXPLORATION OF THE SEA.

instance in the huge Gulf of Guinea, waters from the deep rise to the surface and become the seat of a large outburst of planktonic life which imparts a distinct tint of green to the water. From these areas of fertility and abundance the waters spread by the currents become progressively poorer in the salts necessary for plant growth, and the life areas of the ocean where the water is of a pure blue can only be compared to deserts supporting a minimum of life.[4]

At best sea water is a very dilute solution of many of the materials, such as phosphates and compounds of nitrogen required for the growth and multiplication of plants; and, of course, the animals are dependent upon the plants. Concentration of some of these food substances in sea water is many times less than in good soil. Correspondingly, marine plants must be adapted to derive nutriment from an extremely weak solution. Put in another way, they must have greatly extended surfaces relative to size of body to permit of a maximum efficiency in absorption through the surface. In short, they must generally be of minute size, since the smaller the body the greater the ratio of surface to volume. In contrast then to the trees, shrubs, weeds and grasses of the land we find the predominant vegetation of the sea in the form of exceedingly minute yellowish and brownish algae such as the diatoms and the more minute Coccolithophoridae.

As Brooks pointed out long ago, it is advantageous for the new plant cells which are formed by cell multiplication to separate from each other as soon as possible in order to expose the whole of their surface to the water. Cell aggregation and specialization in form have not taken place among marine plants in any way comparable to what has occurred with terrestrial vegetation.

In another way, and in further consequence of its chemical surroundings, the marine organism faces a different and simpler problem than does its relative of fresh water or of land. Living continuously immersed in a solution not differing so widely in salt content from its own body fluids, the alga, the protozoan,

[4] Krogh, 1934, pp. 423–424.

the soft-bodied larva or adult of higher groups require relatively little protection against disturbance of the chemical balance, losses to the environment through diffusion or desiccation.

Organic Wastes

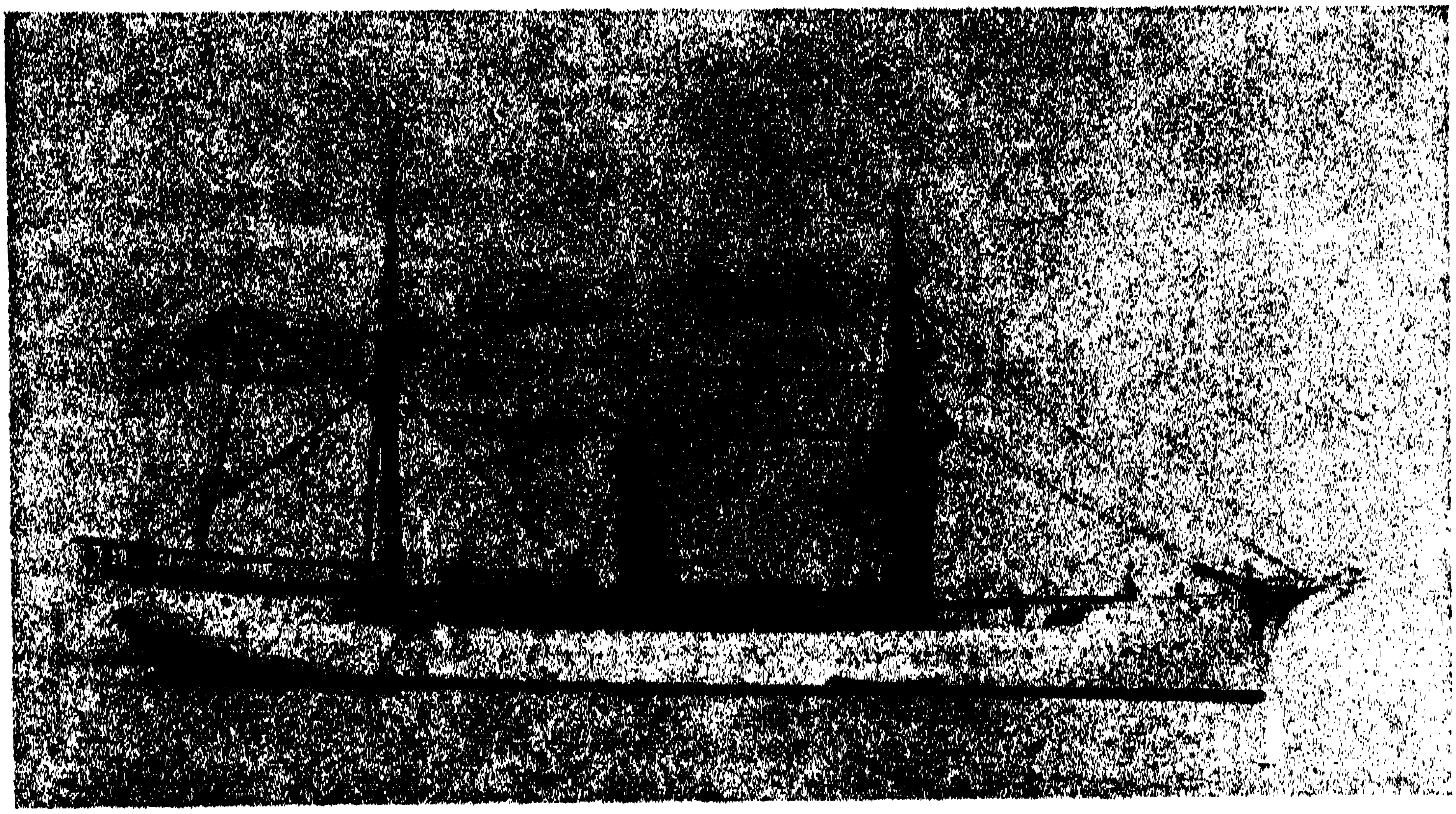
On land, leaves, twigs and other parts of plants and the wastes of animals fall a distance of a few feet to the ground to decay and become the nutrients of other plants or to furnish food for small animals or for the bacteria of decomposition, which in turn are eaten by animals. In ponds and lakes the organic wastes likewise accumulate on the bottom and there harbor a luxuriant community of scavenger animals and bacteria. In the great open sea, however, the fall extends through a long distance and since the bodies of the predominant populations of the sea are minute, the rate of sinking is exceedingly slow. Even a large copepod falling at a rate of about one centimeter per second (or a couple of feet a minute) would require a couple of days to reach a depth of a mile, but protozoa, diatoms and coccolithophores must sink at vastly slower rates. Meanwhile, the living animals of intermediate depths are all to be supported and what other source of food than the downfalling bodies is available for such animals? There is also ample time for the dissolution of the small bodies, so that in areas of great depth even calcareous and siliceous skeletons may be completely dissolved before the bottom is reached. It appears that, barring the extensive deposits of skeletons in regions of appropriate depth, there is no great accumulation of solid organic wastes in the depths of the sea.

On the other hand, there is a considerable accumulation of organic matter in solution, which, although in dilute solution, is substantial in amount. Is this material utilized in the depths or does it represent in considerable part an irretrievable loss to the organic world? Krogh (1934) has estimated that the dissolved organic substance is equivalent to some three hundred times the amount of living organic material in the sea at any one time. He calculates that the Atlantic Ocean has dissolved organic matter equal to 20,000 times the world's wheat harvest for one year; he suggests the possibility that this material has "in the main gone out of organic circulation," that it is unrecoverable and is possibly accumulating. We know little, however, of the capacity of bacteria and other organisms of the depths of the sea to utilize the dissolved organic matter.

Pressure

Pressure in the ocean, increasing by one atmosphere for every 33 feet of depth, varies from one atmosphere (15 lbs. per square inch) at the surface to nearly 1,000 atmospheres at the greatest depth. It is obvious, of course, that the greatest difference in pressure to which a terrestrial animal may be subject in passing from the lowest level of exposed land to the top of the loftiest mountain peak or even to the greatest height to which a bird can soar, must be considerably less than one atmosphere. So great is the pressure even at 1,000 meters (a little over 100 atmospheres) that a block of ordinary wood, it is said, would be reduced to half its volume through the squeezing out of air ordinarily imprisoned in the cell spaces and would sink instead of floating: and a similar statement would apply to cork.

It is an old but, as it now seems, a very irrational assumption that the conditions of pressure that prevail in the depth of the sea were inconsistent with the existence of life. An *azoic* area beyond the depth of some 1,800 feet (600 meters) was once conceived to exist. Not only have explorations with deep sea trawls, dredges and plankton nets revealed the falsity of such an assumption, but obviously there was no *a priori* reason for it.



THE "ALBATROSS"—OF THE U. S. BUREAU OF FISHERIES
PROBABLY THE FIRST SHIP DESIGNED FOR EXPLORATION OF THE SEA.

It is a quality of liquid as of gas that pressure at any level is uniformly distributed in all directions. Consequently, for an organism adapted to the pressure, it is no more to be supposed that the animal should suffer from it than that we should be overwhelmed by the atmospheric pressure of some fifteen pounds to the square inch which we endure—let us say, some tens of thousands of pounds of pressure upon the body as a whole.

Nevertheless, the change in pressure with depth does interpose some barrier to the vertical migration of animals. If we suffer in undergoing the relatively slight modification of pressure within the limits of a single atmosphere when we ascend to an elevation of 10,000 or 15,000 feet or descend only a few meters into the water, what must be expected to be the physiological effect upon a marine organism which in its daily or seasonal wanderings may undergo changes of pressure to the amount of several atmospheres? One of the most noteworthy qualities of marine organisms is their capacity for rapid adaptation to great differences in pressure. To take only one conspicuous example, how does the whale escape the "caisson disease" when it "sounds" to pass in a few minutes through ranges of pressure that would completely wreck a human system even if it were allowed an almost indefinite period for the transition?

The whale, according to the best records, may dive rapidly to a depth of about four fifths of a mile, but not all marine animals are so adaptable. As Dr. Herdman has said, "If deep sea fishes accidentally get out of their accustomed depth and pressure, the expansion of air in their swim-bladders renders them so buoyant that they continue to tumble upwards to the surface, helpless, and eventually killed by the distention of their bodies and the disorganization of their tissues due to the diminished pressure. They die a violent death from falling upwards."[5]

Viscosity

Viscosity of sea water varies with the temperature, being nearly doubled by a fall of 20° C., although the change in viscosity is not precisely parallel with the change in temperature but increases

[5] Herdman, 1923, p. 161.

much more rapidly in the lower range. In consequence of the relation between viscosity and temperature, an object may sink much more rapidly at the surface than in the colder waters below. But any object will continue to sink if its specific gravity is higher than that of sea water at zero degrees. The old idea that sinking ships are arrested in their fall at some level of intermediate depth is, of course, without foundation. A wooden ship would indeed attain a greater sinking velocity as the pressure reduced its displacement by squeezing out the air from the wood cells. Contrary to what might be surmised, pressure does not materially effect viscosity. "The viscosity of pure water is even somewhat reduced by high pressure at temperatures below 32° C."[6]

The viscosity of the medium offers two of the marked contrasts between life in the water and life in the atmosphere. As any swimmer or any designer of automotive craft well knows, it requires a very much greater expenditure of energy to propel a body through water than it does to drive it through the atmosphere. One might suppose, then, that aquatic animals were necessarily slow of movement as compared with terrestrial animals, but again we find such adaptations of form and locomotive power that the speed of the swiftest animals of the sea, such as the bonitos and related fishes, and even bulky animals like porpoises and the larger whales, are capable of velocities of movement that compare well with (without perhaps equalling) those of the swiftest of terrestrial or aerial animals. There are, however, comparatively few marine animals with rates of locomotion comparable to the myriads of swift flying insects on land.

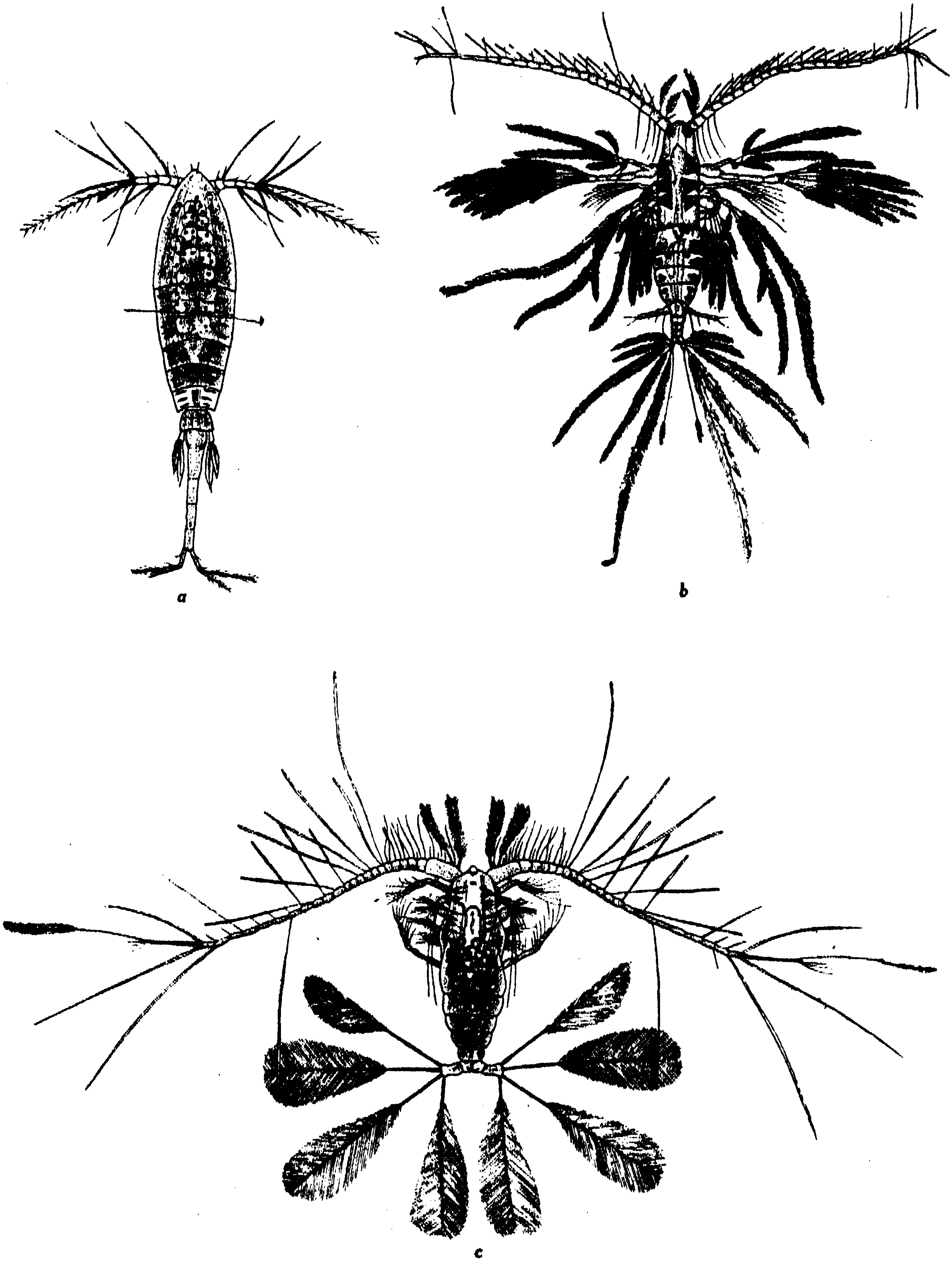
The viscosity of sea water has a further significance to organic life in water in that it retards sinking: but sinking velocity is also a function of form. Because of the inverse correlation of viscosity with temperature the viscosity of water, unlike its salinity, varies materially with the season. A peculiar phenomenon that has engaged the attention of many students of the drifting life of sea and fresh waters is the seasonal change of form manifested by some short-lived plants and animals. The change occurs not in the individual from time to time, but in successive generations; thus at any given time the animals (or the plants) may be quite different in appearance from their ancestors or from their descendants living within the same year but at other seasons. There seems clearly to be a variable adaptation between form and viscosity, but it is not so evident whether the change in form is actually induced by the changing viscosity or by changing temperature or by other conditions that vary concomitantly with temperature.

[6] Krogh, 1934a, p. 431.

Density

The density of specific gravity of water is correlated with its salinity and is a measure of the effective weight of animals or plants in the sea. The specific gravity of sea water, of salinity of 35 parts per 1,000, is about 1.02813 at 0° C., but it is greater at lower temperatures and less at higher, and slightly greater under high pressure (1¾ per cent. greater at 400 atmospheres—Murray and Hjort).

The protoplasm of marine animals is not greatly different from those of terrestrial animals, but the former live in a medium of approximately the same specific gravity as the living parts of their bodies, while the latter are surrounded by a medium of far less density. The support of the body against the pull of gravitation presents a problem to the terrestrial animal that must be met by adaptation in form, appendages, skeleton and muscles. This problem is less acutely felt by aquatic animals in fresh water, and much less so by those of marine habit. Even when on occasion the problem of support is not successfully met, the fall



COPEPODS
(a) *Lubbockia squillimana*
(b) *Augaptilus filigerus*
(c) *Calocalanus pavo* (ALL AFTER GIESBRECHT).
IN "B" AND "C" ARE SEEN THE EXTREME DEVELOPMENT OF PLUMOSE SETAE AS SO-CALLED "FLOTATION PROCESSES."

of an animal on the land is a much more violent occurrence than the fall of an animal in the water. In the plant world as well, the differences in form and structure of terrestrial and marine plants are probably related in very large measure to the differences in density of the respective media in which they have their being.

Doubtless all marine animals and most marine plants are somewhat heavier than the surrounding media except as they have special buoyancy organs. But any one who has witnessed the explosion of dynamite in the water knows that some of the dead bodies rise to the surface, while others sink to the bottom. The problem for non-benthonic aquatic animals (those not living on the bottom) generally is that of keeping above the bottom rather than that of staying beneath the surface; falling to the bottom, it may be understood, is a serious matter, when the bottom is several miles removed and marked by conditions of pressure, temperature and darkness that may not be tolerable to organisms of the upper strata. Keeping within a zone of tolerable pressure represents for animals in the sea a problem to which there is nothing comparable for animals on land—the problem of falling neither downward nor upward to levels of extremely different conditions of pressure. Gas bladders, accumulations of fat or oil droplets contribute to buoyancy, while in both animals and plants notable extensions of the body surface, the so-called "flotation processes" offer resistance to sinking or serve as keels and rudders to facilitate movement in a horizontal or upward direction.

In this connection, as in others, reference may be made to the minute size of the vast majority of organisms of the sea, a condition that seems not to prevail to the same degree with land and freshwater organisms. Doubtless, also a great number of small organisms quickly disintegrate after death into still smaller particles. Rate of sinking is a function both of weight and of the frictional resistance to movement through the water, and friction is a function both of the viscosity of the medium and of the surface area in contact with the medium.[7] The more viscous the medium and the greater the surface in proportion to mass, the slower the rate of falling. It is a well-known law that the smaller the object the greater is the surface relative to volume. As Krogh (1934, p. 423) has expressed it, "the rate of sinking of the minute plankton organisms is so slow that they can remain in the upper strata of the water for the length of their natural lives." But this does not answer the problem, for, unless the rate of sinking were zero, each succeeding generation would begin falling where the preceding generation had left off; so that after a few generations the bottom would be reached by all and the upper strata would have become entirely depopulated.

The rate of sinking can be zero only if the viscosity were infinitely great—that is to say, if the ocean were solid, which it is not; or if the ratio of surface to volume were infinitely great, which is impossible; or finally, if the organisms were of like weight with the water in which they live. Should the last condition prevail, there would be no need to invoke either viscosity of the medium or size and form of the organism as factors

[7] By Stokes' law the rate of sinking is inversely proportional to the viscosity but directly proportional to the difference in specific gravity between the body and the medium. Sinking rate also depends upon size, varying with the square of the radius, and upon form. Stokes' law holds only for a small sphere, whereas the bodies of plankton organisms, which are generally of more or less irregular form, offer a special resistance derived from the increased area exposed to the medium. As the dead body sinks there is also the possibility of its taking up salts to bring its specific gravity nearer to that of the medium and thus to reduce its sinking velocity. There enters in also the influence of "eddy viscosity"—arising from conditions too complex for present discussion.

of retardation, since there would be no tendency to sink—nothing to be retarded. We might, however, assume that sinking at a very slow rate does occur, but that either some compensatory capacity for upward movement was inherent in the smallest organisms or that upward currents in the water lifted the organisms as much as they sank. The mechanics of flotation of non-motile or weakly motile organisms is not a fully solved problem. The phenomena of viscosity to be encountered are by no means so simple as might at first be thought. The sea is not static: there are movements of animals, of plants, even if only sinking movements, with accompanying disturbances of smaller or greater masses of water. Anywhere, too, there may be drifts or currents as yet little known, but producing correlative viscosity effects which can now be imperfectly analyzed by the most expert mathematician.

ATTACHING THE WATER BOTTLE TO THE HYDROGRAPHIC CABLE ON THE "CARNEGIE"
COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

The contrast in density of sea water and fresh water is illustrated by the fact that many marine fishes have eggs that float at the surface, while all eggs of fresh-water fishes sink to the bottom, or are "demersal." Floating eggs are almost unknown in fresh water except among amphibia and some cladocera, occasionally, and a very few insects.

As a final word in this brief consideration of the subject of specific gravity, it may be remarked that the dead bodies of marine animals and plants must generally sink to the bottom except as they are devoured by scavengers or become dissolved in the water in the course of their long descent. Since sinking velocity varies directly with the size of the body, the smaller animals and plants are the more likely to be dissolved or to be devoured and later to reappear in part in new forms as soluble metabolic wastes of the "consumer." Bodies of larger organisms, sinking much more rapidly and dissolving more slowly, have the greater relative chance of reaching the bottom. Nevertheless we shall see later that the skeletons of myriads of minute plants and animals make up a large part of the deposits on the floor of the ocean. The remains of many large animals too are found at greater depths. Speaking of whales, Krogh (1934a, p. 433) says: "A sinking velocity of 100 m. per hour will bring a body to the bottom in most places in less than two days. At one station in the Southern Pacific the Challenger got up in the trawl from the red clay bottom at 4,300 m. (over 2½ miles) several thousand sharks teeth and not less than fifty ear bones of whales but of course it is not known how many thousands of years this accumulation required."

Penetration of Sunlight

The sun is the ultimate source of all the energies of plants and animals, but the greater part of the inhabited region of the earth is always in utter darkness. Even in the illuminated parts of the biosphere, light is perhaps the most variable of all conditions of the environment, for each day the light may fluctuate from the full daylight of noon to the darkness of midnight(Russell, 1936). The penetration of light into natural waters is significant in its physical relations as the different spectral components of daylight are differentially absorbed by the water and absorbed or scattered by dissolved and suspended substances, living or dead, and also as the temperature of the water is affected. Light is most significant biologically, as its intensity and quality affect photosynthesis and the formation of basic organic foods, including vitamins, as they influence the movements of photosynthetic organisms or of those that prey upon them, or as they have stimulative or lethal effects upon organisms brought into the upper strata.

The red component of sunlight is all absorbed, it is said, in the upper 500 meters (1,500 feet), while the rays of shorter wave-length, in the blue-violet end of the spectrum, may penetrate much deeper, to somewhere below 1,000 meters (3,300 feet).[8] It must not be imagined, however, that, practically speaking, absorption is uniformly or regularly proportionate to wave-length. Ultra-violet rays, or those just beyond the limit of visibility on the short-wave end, scarcely enter sea water at all. There are, moreover, considerable differences in the absorption of the several components of visible sunlight in different regions. Thus Oster and Clarke say that green and blue penetrate equally well in the Gulf of Maine (violet less well), but that blue goes deepest in the transparent water of the Sargasso Sea. Always the sea water is least transparent to red.

EMPTYING WATER BOTTLES OF SAMPLES TAKEN AT VARIOUS DEPTHS
COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

[8] Hjort, from his own experiments, says that light penetrates to a depth of 1,000 meters (3,280 feet), but not to 1,700 meters. Beebe, on one of his descents in the bathosphere near the Bermudas, found light still visible to the eye at 1,900 feet (579 meters), but not the faintest hint of illumination at 2,000 feet. He adds (1935): "A problem of color not yet explained is that from 200 feet down, through the spectroscope, the blue is gradually replaced by violet, until at a depth of 400 feet the latter color is dominant. Yet, to the eye, at no time of the descent is there any trace of violet or lavender, only the strongest of blues, appearing brilliant long after it has lost all power for actually seeing anything in the bathysphere."

Matter in suspension has much to do with absorption and scattering of light rays and thus with the visible color of the water. The short blue and violet rays are most effectively scattered by suspended particles, and, with the red and yellow wave-lengths quickly absorbed (converted into heat), green is left as the apparent color of the water where suspended matter is abundant. The less the numbers of solids or the more barren the water, the more regularly are the light rays absorbed in inverse proportion to wave-lengths and consequently the bluer the water.

THE MONACO MUSEUM OF OCEANOGRAPHY
FROM HERDMAN.

The photic zone has been said to be the upper 1,000 meters (500 fathoms) in the clearer waters of the open ocean, but it is much less near land in higher latitudes. Indeed, the more conservative writers place the lower limit of photosynthetic activity at 200 meters or less. We may feel reasonably sure that photosynthetic plants can not live much below 1,000 meters, and doubtless few, if any, live at such a depth. Nevertheless, the green algae, Halosphaera, is reported to have been found by the plankton expedition at a greater depth. Minute plankton plants may on occasion fall slowly into the darker depths where conditions will not permit their continued growth and reproduction, but where they may continue to exist until devoured by the small plankton animals or lost by death and dissolution.

Except within the tropics the sun's rays strike the surface at an angle even at mid-day on the summer solstice; at all other times of the day, everywhere, the angles of incidence of the rays are such that a substantial proportion of the total sunlight must be reflected from the surface during the morning and afternoon hours. Harvey says that even in pure water about half the energy (light plus) is absorbed in the first meter and about 20 per cent. more in the second. Shelford and Gail (1922) tell us that even in the middle of the day, between 10 A.M. and 2 P.M., about a fourth of the sunlight falling on the water's surface in Puget Sound is reflected and that the light that penetrates is absorbed so rapidly as to be reduced by a fifth at a depth of one meter. Only 8 to 10 per cent. of the shorter wave-lengths entering the surface reach a depth of 10 meters. These data apply to conditions in calm weather; in rough weather 60 or 70 per cent. or even more may be blocked at the surface.

The length of the period of daylight is not the same beneath the surface as above it. Another observer has said that at a particular place, when the day at 20 meters was 11 hours long, at 30 meters it was 5 hours and at 40 meters but 15 minutes. The hours of effective daylight are, therefore, less below the surface of the water than above it and the duration of daylight must be the shorter the greater the depth.

The refractive power of water, or its capacity to bend light rays toward the vertical is to some extent a compensating feature permitting the rays that do enter to reach a greater depth. It may be noted, too, that much of the light that strikes the surface comes, not in direct passage from the sun, but by reflection from the sky. It would seem, nevertheless, that the maximum possible utiliza-

tion of sunlight and photosynthesis could not be as great in water as on land.

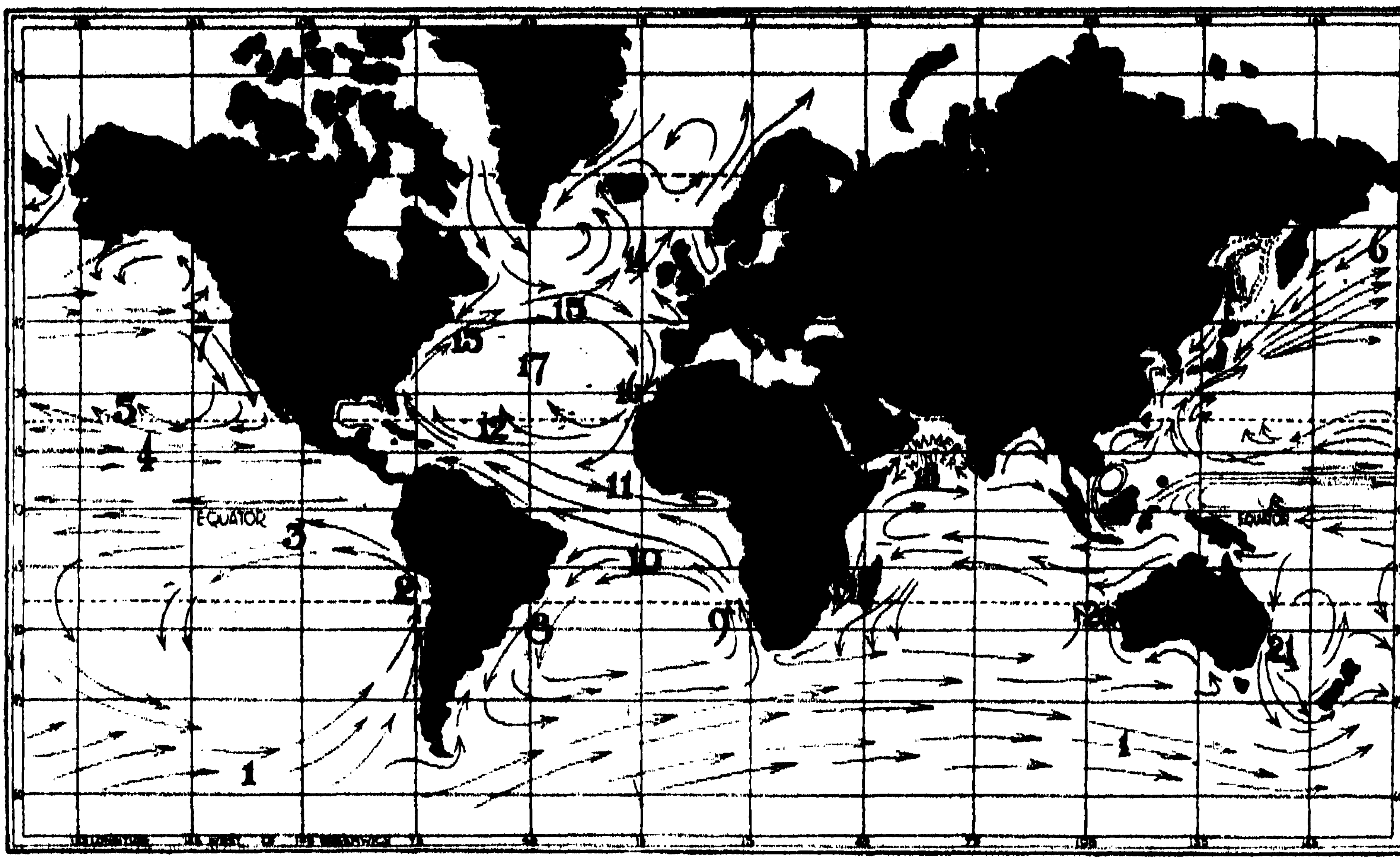
It must be kept in mind that, regardless of the depth of the sea, the total available sunlight in a given latitude and under given atmospheric conditions is a function, not of the volume of the body of water or the size of the body of the plant, but, rather, in each case, of the area of exposure. The amount of sunlight available for the production of organic material by plants is not, then, beyond certain limits, affected by the depth of the sea. To what extent other conditions than the availability of sunlight place a limit to its utilization on land or in water, may not be fully known, but the facts cited suggest the possibility that productivity as based on photosynthesis is at best restricted in the sea as compared with a corresponding area of land; and such a surmise would be equally applicable to bodies of fresh water. Animal life as a whole can not transcend or even equal their supply of vegetable food, but the animals in any one place are not always restricted to the plant food produced in that particular place. Nevertheless, in view of the disproportion of land and oceanic areas, the contribution of vegetable matter from the land to the sea must be relatively insignificant for the oceans as a whole, although, no doubt, of considerable importance to a narrow zone of coastal waters. In fresh water, on the other hand, the disproportion is quite the other way and the contribution of land vegetation to the basic food supply of animals in small lakes and streams may be relatively very considerable.

We need not, however, permit the logic of the stated facts to lead us to final or dogmatic conclusion. We may not have all the facts. Besides confessing ignorance as to what conditions, other than the physical availability of sunlight, affect the efficiency of plants in its utilization, we must face the special condition of the plant life of the sea: the bulk of the photosynthetic agents in the ocean is composed of an extraordinarily large number of exceedingly minute plants; protophytes whose dimensions are measured in a few thousandths of a millimeter. How, then, the enormous aggregate surface exposure of the marine phytoplanktons affects the total photosynthetic effect and the productiveness of the oceans as a whole is not a question to be lightly answered.

OCEANIC CURRENTS AND DRIFTS

The movements of water in the sea, apart from the lunar tides which involve only relatively small and local surface shifts of water, and the sun tides which, to some extent, reinforce or oppose the lunar tides, are governed by the winds, by influences associated with the rotation of the earth and by evaporation and its effect on salinity and specific gravity. In general, the great currents flow clockwise in the northern hemisphere and counter-clockwise in the southern. Principal of these are the east-west equatorial currents in the Atlantic and Pacific Oceans, the northeastward flowing "Gulf Stream"[9] in the western North Atlantic, the great Japan Current (Kuro-Siwa—"black tide") of the western North Pacific, and the Peru or Humboldt Current of the eastern South Pacific. The major currents of the sea are actually powerful streams obvious to the senses. The Humboldt Current lends itself particularly well to observation, since there occur in its path islands near which one may anchor and, even there where the flow must be retarded by the obstruction, one may both see and hear the flow of water, moving in one direction as ceaselessly and as rapidly as the streaming of a great river. To the great stream

[9] Perhaps incorrectly so called, since its waters are now presumed to come almost exclusively from the Caribbean following a direct route from the Yucatan Channel to the Straits of Florida along the north coast of Cuba.



OCEAN CURRENTS. (AFTER SCHOTT)

1. Antarctic West Wind Drift
2. Peru Current (Humboldt)
3. South Equatorial Current
4. Counter Equatorial Current
5. North Equatorial Current
6. Kuro Siwa
7. California Current
8. Brazil Current
9. Benguela Current
10. South Equatorial Current
11. Guinea Current
12. North Equatorial Current
13. Gulf Stream
14. North Atlantic Drift
15. West Wind Drift
16. Canaries Drift
17. Sargasso Sea
18. Monsoon Drift (Summer East, Winter West)
19. Mozambique Current
20. West Australian Current
21. East Australian Current

just mentioned we might add the Labrador Current, which flows southward following the eastern border of the Grand Banks and then turns outward flowing somewhat parallel to the Gulf Stream which has here a northeastward trend.[10] These great currents are relatively surface phenomena, but we might refer also to the more leisurely "drifts" of abyssal waters, such as that of the Antarctic waters that are presumed to flow northward across the equator and over the bottom of the North Pacific. The rate of flow at great depths has been estimated at about 1½ miles per day. In the Atlantic the main body of the deeper water seems to move in a southerly direction, with a yet deeper drift of Antarctic water flowing northward as far as 34°–40° North Latitude.

[10] Smith, Soule and Mosby, p. 170, 1937.

Great currents and drifts do not, by any means, tell the whole story of the dynamics of the sea. There are deep tidal waves of great amplitude that may influence the whole mass of water, and there are diverse turbulence phenomena that preclude analysis in simple language.

Slow upwelling movements are also known to occur along the western shores of North America, South America and Africa. The rate of upwelling along the coast of Southern California has been estimated by McEwen as of the order of about one meter per day—a slow rise, indeed, but fast enough to be, as we have already suggested, of great significance in restoring to circulation in the upper waters the dissolved materials that would otherwise be irretrievably lost in the abyss. The upwelling of cold abyssal

waters tends also to lower the temperature of coastal waters. Thus the coolness of the waters that bathe the coasts of California in the northern hemisphere and of Peru in the southern hemisphere is not due entirely to the surface currents flowing toward the equator from Arctic and Antarctic regions, respectively. Indeed, it is said that the waters of the western coast of North America actually become colder in places as they move southward, and surely the surface waters of the Humboldt Current are warmed but slightly as they flow along the coast of Peru for more than a thousand miles beneath the clear tropical sun.

Again, there are vertical movements arising from differentials in specific gravity. When evaporation has so concentrated the superficial waters as disproportionately to alter the specific gravity, the heavier concentrated waters must sink below to be replaced by more dilute and higher waters from beneath. Vertical movements from this cause are perhaps not very significant as suggested by our comment in a later paragraph. In higher latitudes the cooling of surface waters increases its weight so that wherever it overlies warmer and higher waters there must occur convection currents that cause an interchange of positions. There may, too, be other causes of vertical movements that are less well understood.

Were it not for some sort of mixing apparatus, the sea water would have diverse chemical composition and very different concentrations in various parts

SUNSET ON THE PACIFIC OCEAN

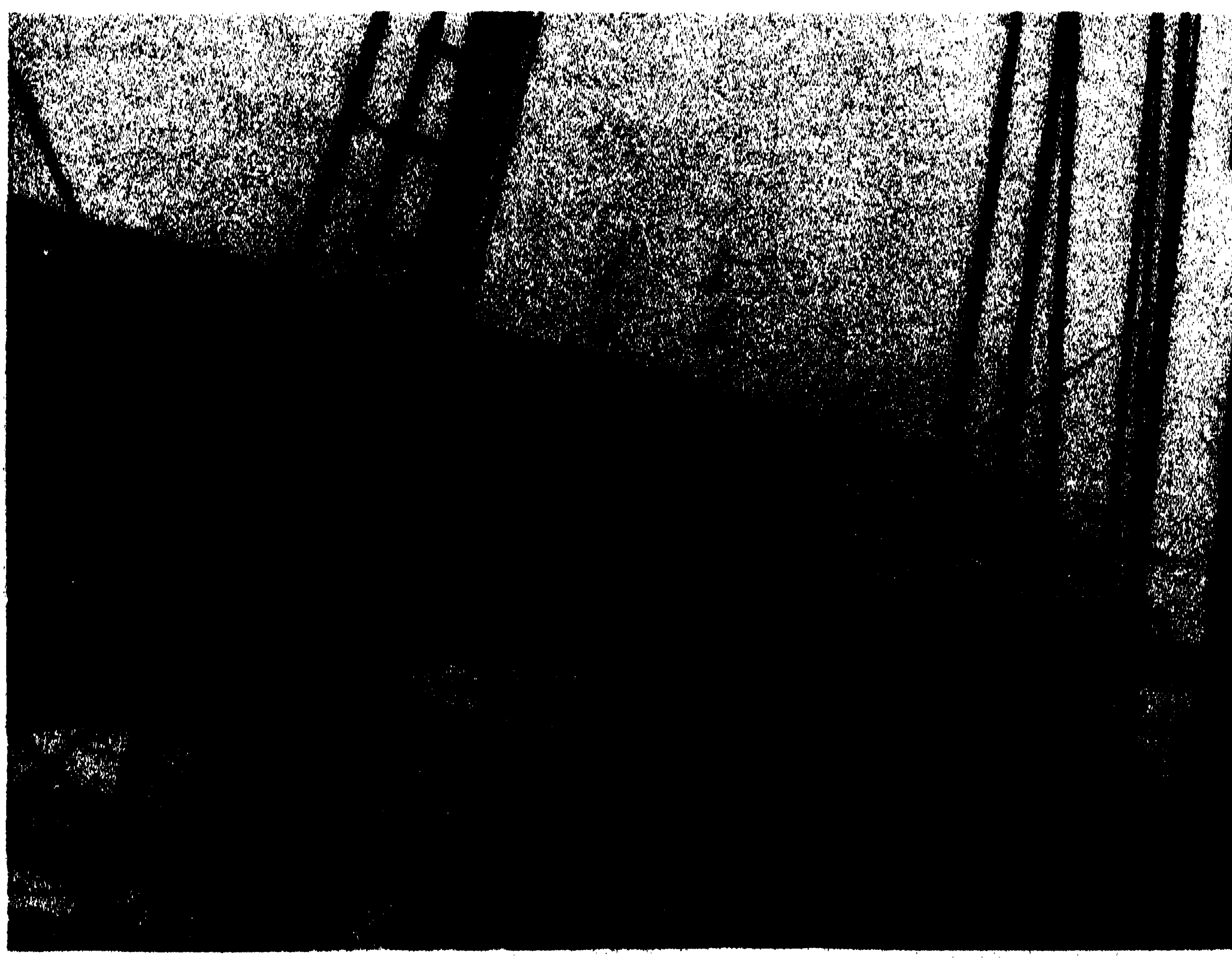
TAKEN FROM THE "CARNEGIE." COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON (C2409).

of the world; but we have seen that this is not the case. A mixing apparatus on a grand scale is formed by the currents and drifts, the upwellings and convection currents and the oscillations and turbulence phenomena to which allusions have been made. The sea is not a static body, but everywhere a dynamic one.

THE BOTTOM

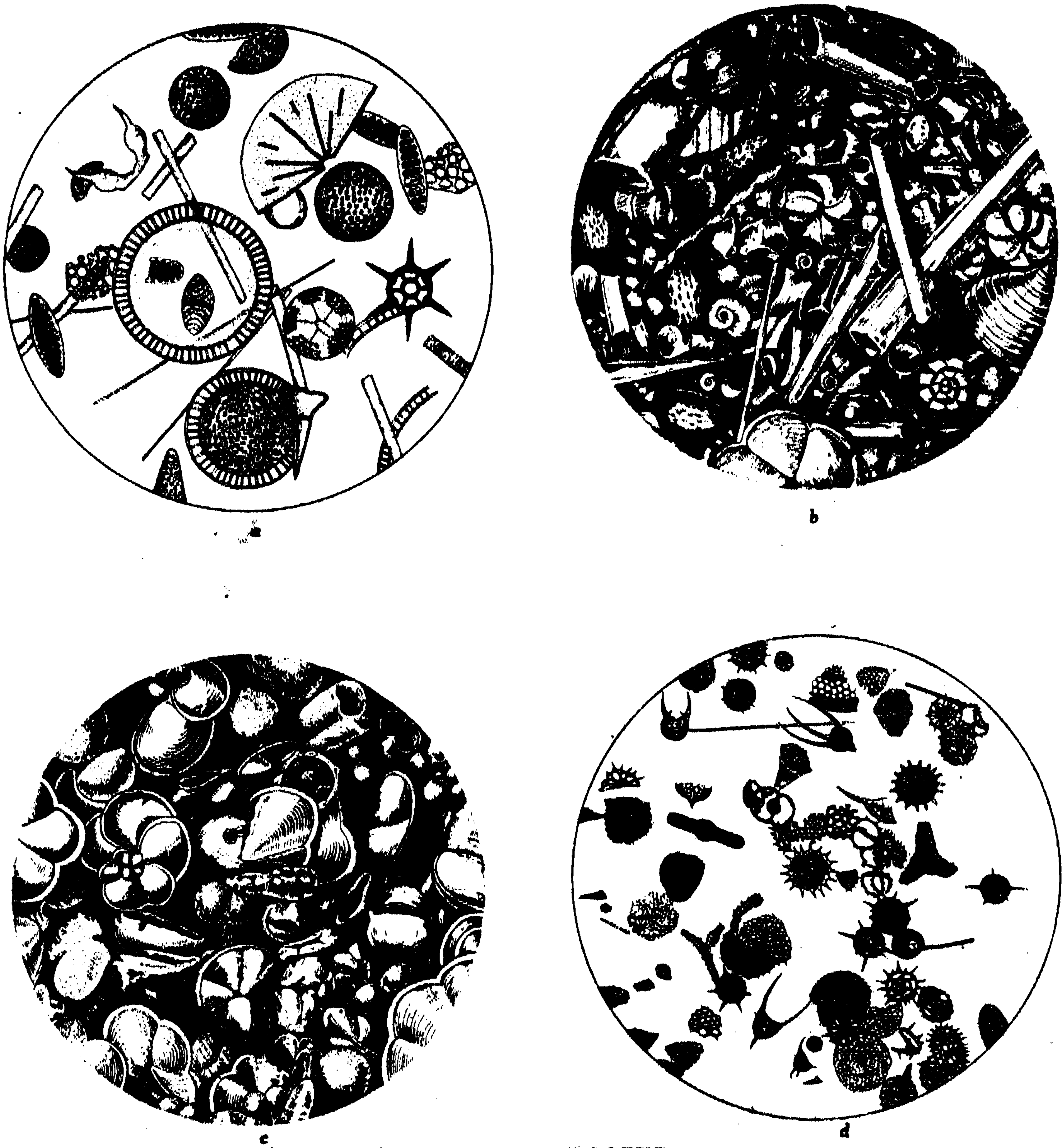
The bottom is covered by deposits of various kinds which may be considered in three chief groups: (1) *Terrigenous*, about two thirds quartz and other mineral matter washed down from the land and being some 68 per cent. silica; (2) *Neritic*, consisting of materials from the land mixed with organic substances formed in the shallow coastal waters, such as the remains of mollusks, crustacea, echinoderms, worm tubes, etc.; and (3) *Pelagic*, comprising materials originating almost exclusively in the sea or coming from the atmosphere or interplanetary spaces. Terrigenous and Neritic deposits are, of course, found chiefly on the Continental Shelf. The Terrigenous deposits are the shallow water sands and muds, in which quartz grains constitute a prominent part, and the deeper red, blue and green muds, with colors due to predominance of different mineral substances, such as oxides of iron and manganese and glauconite (silicates or iron and potassium); with the Terrigenous deposits may also be listed the volcanic muds and coral sands and muds of certain regions.

The Pelagic deposits comprise four chief "oozes" of organic origin and "Red Clay." *Diatomaceous Ooze* is found almost exclusively in cold regions of the



THE SEA IS NOT ALWAYS SMOOTH

THE "CARNEGIE" MEETS HEAVY SEAS IN THE SOUTHERN OCEAN. (C1863) COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.



THE PELAGIC OOZES
(a) DIATOM OOZE (FROM STEUER AFTER CHUN)
(b) PTEROPOD OOZE (AFTER MURRAY AND HJORT)
(c) GLOBIGERINA OOZE (AFTER MURRAY)
(d) RADIOLARIAN OOZE (FROM STEUER AFTER KRÜMMEL)

Antarctic and of the southern and far northern Pacific at 600–2,000 fathoms. The siliceous shells of diatoms are found in such deposits in extraordinary numbers. The calcareous *Pteropod Ooze*, comprising the shells of the pelagic mollusks (pteropods and heteropods) mixed with shells of Globigerina and other materials, occur principally in tropical regions at less than 1,000 fathoms. Two kinds of pelagic Protozoa contribute materially to the floor of the ocean. About 40 per cent. of the floor of the north Atlantic, and perhaps one third of the total area of all sea bottom, is covered by *Globigerina Ooze*, composed in considerable part of the calcareous shells of the foraminiferan *Globigerina bulloides*, mixed with coccoliths, to be mentioned later; this deposit is about 65 per cent. calcareous mat-

ter and is found at 1,000–2,500 fathoms. Although it was once supposed that Globigerina Ooze was the basis of chalk deposits, it is now believed that the chalk was formed in shallow seas and that such deposits do not, therefore, represent old deep sea bottoms.[11] In contrast to the calcareous ooze just mentioned, is the siliceous *Radiolarian Ooze,* consisting of a foundation of red clay in which are mixed the remains of Radiolarian shells; it occurs at 2,500–5,000 fathoms in isolated areas of the tropical Pacific and Indian Oceans. Finally, the *Red Clay,* constituting more than half of the floor of the Pacific and about one third of the combined area of the floor of all the seas, is composed of silicates of aluminum, iron and manganese, volcanic dust, interstellar dust and, in small part, of the residue of organisms. This Red Clay of the sea bottom is not to be confused with the red clay of the land. The color of the submarine Red Clay is believed to be due to oxides of iron and manganese derived from volcanic dust. It accumulates with exceeding slowness; Sir John Murray has estimated that there has been an increment of about one foot since Tertiary times! There is no rock in the geological series that corresponds to the Red Clay of the ocean floor, and this leads us to believe in the relative permanence of the deeper parts of the seas; no present area of land seems to comprise what has ever been the red clay areas of sea bottoms.

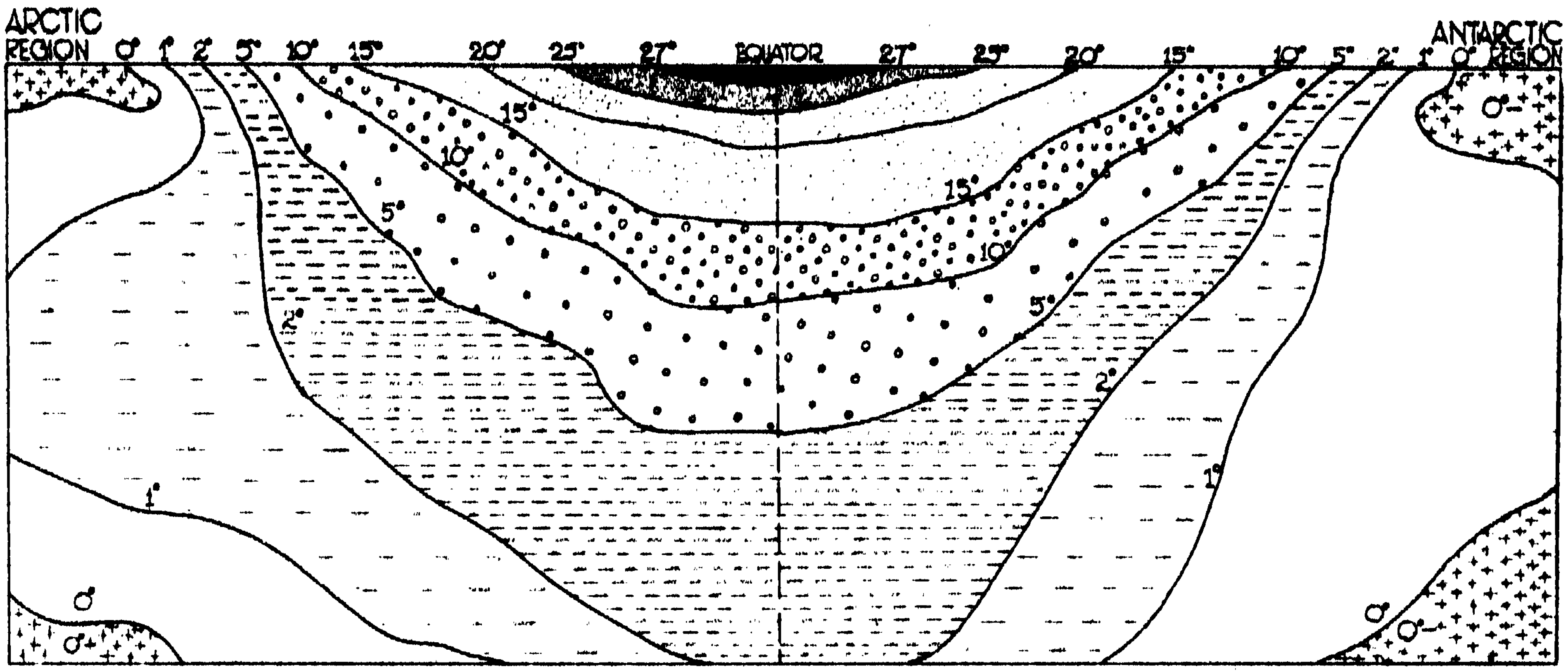
TEMPERATURE

The temperature of the surface water in the ocean varies with seasons and with latitude, but the temperature in any given latitude is not uniform from east to west. Because of the currents previously alluded to, which convey great masses of equatorial water toward the poles and others that return waters from Arctic and Antarctic regions toward the tropics, and, in part, because also of sinking and upwelling movements of the water in different regions, the seas are warmest in the eastern sides in the northern hemisphere and in the western sides in the southern hemisphere. At the worst, the seasonal variations in temperature are relatively small as compared with those that prevail on land at low altitude in temperate and sub-polar regions and as compared with those of most fresh waters in the same regions. Indeed, beyond a depth of about 200 meters seasonal variations do not occur at all. Differences between summer and winter temperatures of the Atlantic Ocean are least in polar and tropical regions, greatest in the northern temperate zone (10°–50° F.) (5.5°–28° C.). Variations with latitude are notably modified by ocean currents; so that, while comparatively warm water occurs in the course of the Gulf Stream far in the northern Atlantic, surprisingly cold water is encountered in the path of the Humboldt Current very close to the equator in the eastern part of the Pacific Ocean. The drift of icebergs also has an observable effect on the temperature of the North Atlantic, effects that vary with the year and with the shifts of currents.

Unlike fresh water, sea water becomes heavier as it is cooled until its freezing point is reached,[12] so that the limitation of 4° C. for temperatures at the bottom of lakes does not apply in the sea and bottom temperatures of −1° or lower may occur in polar currents; but, although the freezing point of sea water (−1.9° for water with salinity of 3.5 per cent.) is substantially lowered under high pressure, bot-

[11] Bigelow (1931, p. 35) refers to Globigerina Ooze as reported to be accumulating over submarine telegraph cables at the apparent rate of a tenth of an inch a year or a fathom in 720 years, but comments that the sea floor generally over all the vast area occupied by the Globigerina Ooze is certainly not building up at such a rate.

[12] This applies to water with a salinity of 24.7 per M. or higher.



SCHEMATIC REPRESENTATION OF DISTRIBUTION OF TEMPERATURES BY DEPTH AND LATITUDE

SHOWING POSSIBLE CONTINUITY OF ZONES OF LOW TEMPERATURES THROUGH ALL LATITUDES. DEPTH SCALE GREATLY EXAGGERATED RELATIVE TO LATITUDE SCALE. (SUGGESTED BY CHART OF CHUN FOR A RESTRICTED REGION.)

The sketch is crude and makes no pretence of offering a reliable picture of the actual conditions of temperature in any latitude. For a more informative and accurate but more complex representation of the distribution of temperatures in the deeper waters of the Atlantic, see the charts of Georg Wüst in one of the "Meteor Reports:" Schichtung und Zirkulation des Atlantic Ozeans, erste Lieferung: Das Bodenwasser und die Gliederung der Atlantischen Tiefsee: Berlin and Leipzig, 1933.

tom temperatures below the freezing point seem to be very rare; indeed, the temperature of abyssal waters is usually a little above zero, owing no doubt in great part to what Helland-Hansen has called "adiabatic warming"—warming resulting from the effect of pressure. In the North Atlantic generally the bottom temperature is around 2° C. The bottom water is very cold in the tropics as well as in polar regions. "Over 4/5 of the ocean floor exceeds one mile in depth and has a temperature colder than 3° C."[13] The barriers of temperature and pressure that exist between the bottom and the surface at the equator (separated by a distance of 4 or 5 miles) are much more effective than those that exist between two points on the bottom 10,000 miles apart.

The source of heat in the sea is the surface where heat is derived by absorption of the rays from the sun and by radiation from heated air. The amount that can be absorbed is a function of the surface area and also of the heat coefficient of water, which is relatively low. On the other hand, there must occur a great loss of heat through evaporation. The distribution of heat in the sea is affected, in part by the currents that move between warmer and colder parts of the earth, in part by vertical currents brought about by a variety of causes; upwelling movements on the west coasts of the continents have previously been referred to. Evaporation, of course, tends to increase the density and weight of surface water and might be expected to cause it to sink, but vertical movements from this cause are believed to be relatively insignificant—because, where evaporation is considerable, as in warmer regions, its effect in raising specific gravity is more than counterbalanced by the increase in density resulting from the warming of the surface water. The lower salinity of surface water over the Continental Shelf, where the run-off from land is felt, and the higher temperature of surface waters over the seas generally both tend to keep top water on top. Nevertheless, "overturn" occurs in high latitudes, especially in or at the end of winter, whenever the

[13] ZoBell, 1934.

surface-cooled waters become colder and heavier than those beneath them; but the overturn affects, perhaps, only the waters above the thermocline or zone of most rapid change of temperature.

Temperature apparently exerts in many ways an influence on the chemical activities in protoplasm that underlie growth, form and multiplication. Rate of photosynthesis and rates of biological activities in general may be approximately doubled by a rise of 10° C. Temperature governs, to some extent, the distribution of animals and plants and, where a particular species has a range extending through low and high latitudes, its form or the character of its shell may differ with the latitude. Again, as was mentioned in connection with the consideration of density, the form of an animal or plant in a given region may be notably different in summer from that which it has in winter. It is not, however, easily determined whether the differences that appear to go with temperature are governed actually by temperature or by other environmental conditions which are associated causally or accidentally with temperature. In many instances, and perhaps as a general rule, the size that an animal attains is greater when it is reared at a lower temperature.

Gran says: "Temperature, more perhaps than any other factor, determines the growth and decrease of the various species and the character of the communities dominating the plankton. But some species are adapted even to the most extreme temperatures found in the sea and a rich growth can take place as well at the lowest (−1.5°) as at the highest temperatures observed."[14] "Temperature," says Martin (1922, p. 457), "is less directly important in the sea than on land since there is no great danger of injurious extremes being reached. Indirectly, its importance lies in the fact that carbon dioxide is much more soluble in cold water than in warm, and it is probably this, rather than the direct influence of temperature, which accounts for the fact that the most luxuriant development of plant life is in the colder waters of the earth."[15] Allen (1934, p. 175), however, questions the certainty of a generally greater productivity of plankton in high as compared with low latitudes.

[14] Gran, 1932, p. 348.

[15] Martin, 1922, p. 457.

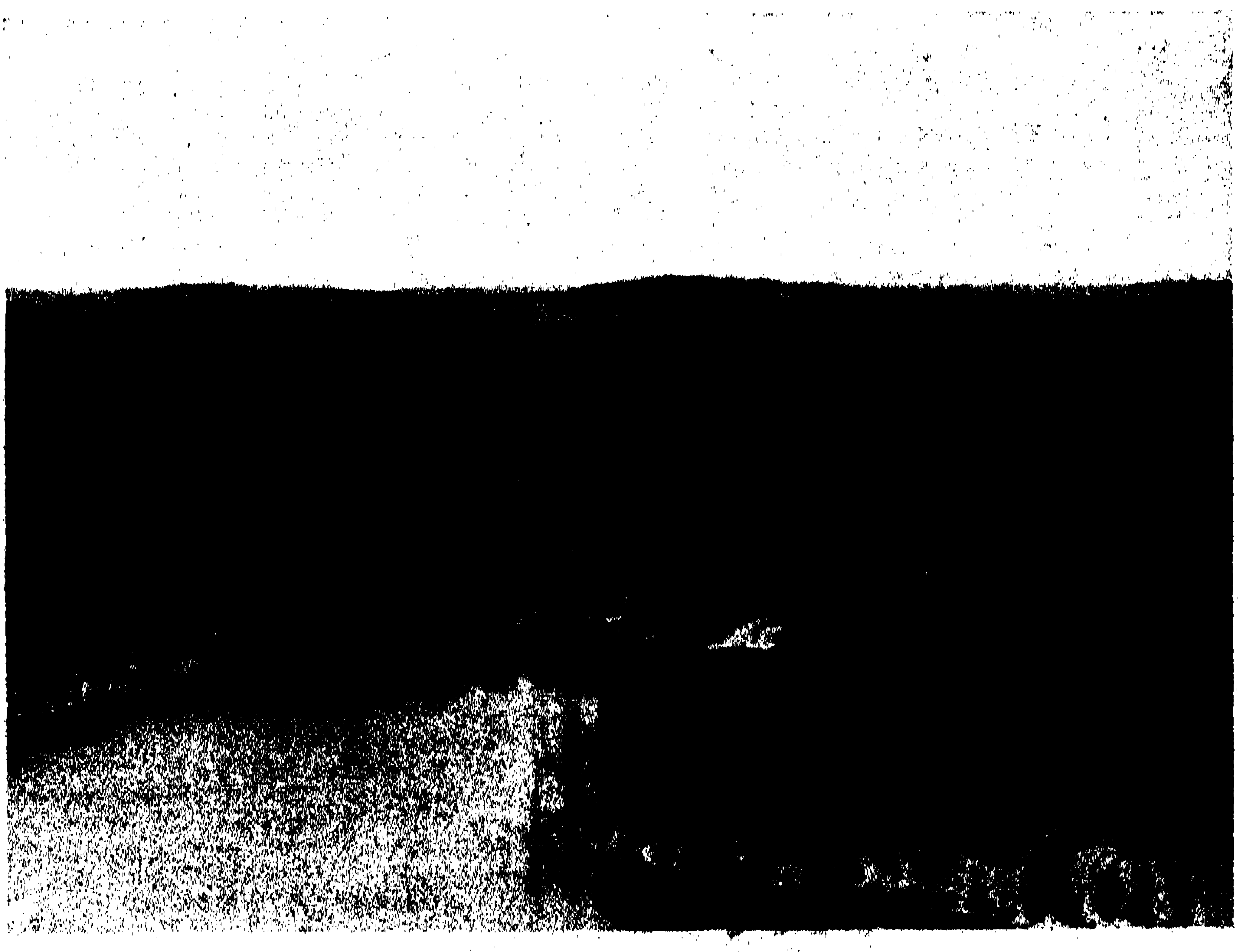
(*To be concluded*)

A STUDY IN PREDATORY RELATIONSHIP WITH PARTICULAR REFERENCE TO THE WOLF

By SIGURD F. OLSON
ELY JUNIOR COLLEGE, MINNESOTA

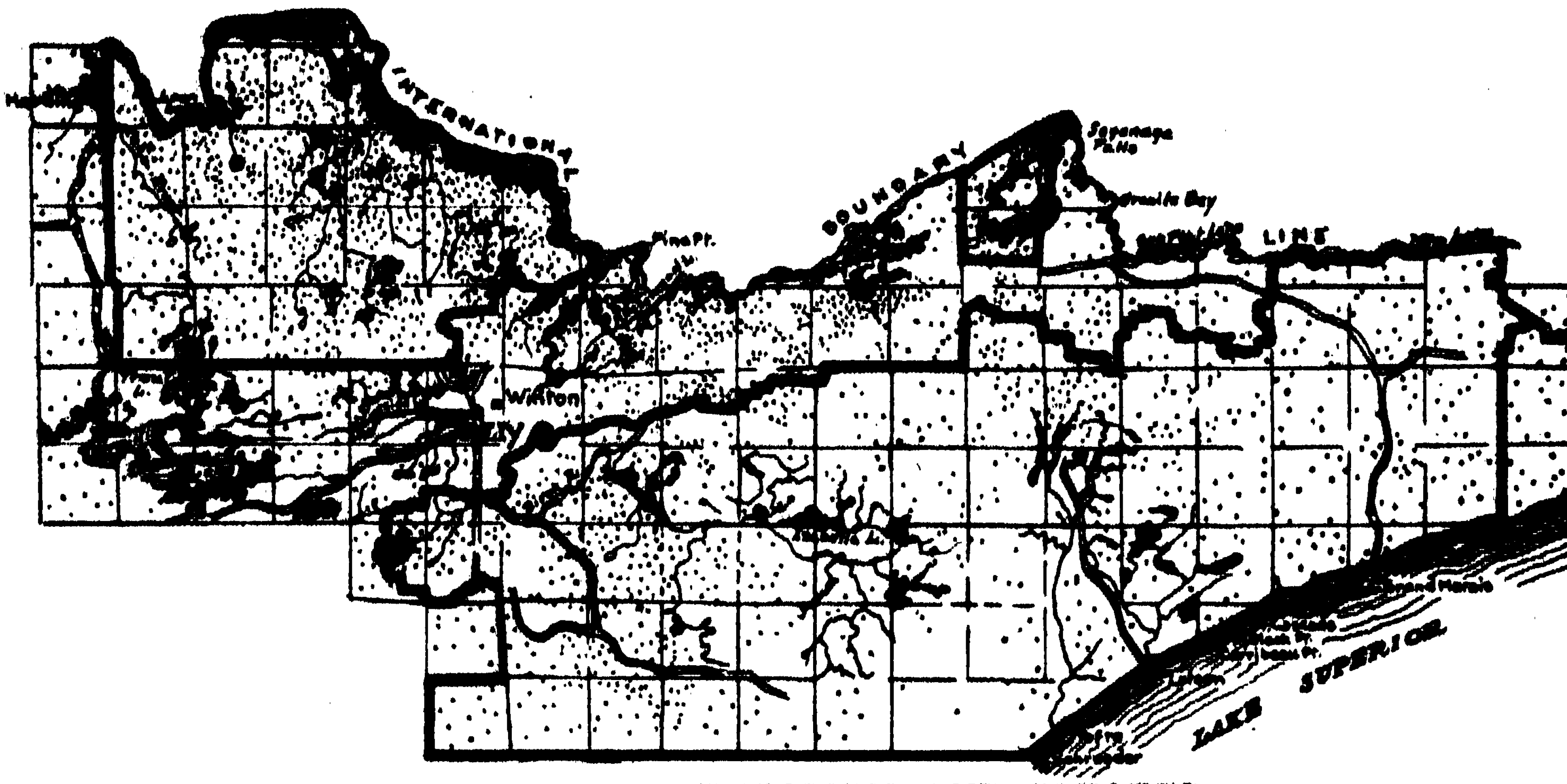
DURING the past quarter of a century, the American people have heard much in regard to the conservation of animal life, but stress has been largely placed on the saving and protection of herbivores at the expense of predatory forms. The predators, those animals which live perforce upon the herbivores, have not as a rule come under the plan of conservation as outlined, and in many areas attempts have been made to eliminate them entirely with total disregard for the influence these forms might have upon the balance of life in the communities of which they are a part.

Game refuges have often been administered as herbivore sanctuaries, until today there are comparatively few areas in which the original animal population can be said to exist under primitive conditions. The tendency has been one of extermination, particularly for the larger



TYPICAL PANORAMA OF THE GAME COUNTRY OF THE SUPERIOR NATIONAL FOREST.

DARK AREAS, LARGELY RED PINE (*Pinus resinosa*), WHITE PINE (*Pinus strobus*), JACK PINE (*Pinus banksiana*), SPRUCE (*Picea canadensis* AND *P. mariana*), AND BALSAM (*Abies balsamea*). LIGHTER AREAS IN THE FAR DISTANCE AND CENTER, ASPEN (*Populus tremuloides*) AND CANOE BIRCH (*Betula papyrifera*). DEAD BIRCHES ALONG THE SHORE OF THE LAKE, DUE TO RAISING OF WATER BY BEAVER DAM AT OUTLET. TAKEN FROM ENSIGN LOOKOUT, JULY, 1932.



DISTRIBUTION OF WOLVES AND COYOTES.
DENSITY OF DOTS INDICATES RELATIVE ABUNDANCE.

predators, the wolf, the coyote and the mountain lion, and little scientific investigation has been carried on to determine the exact status of these forms in relation to the herbivores upon which they prey.

The extermination of predators is no longer a strictly economic problem, for other factors have entered in, factors of scientific, recreational and esthetic value. With the fast-growing appreciation of the true meaning of wilderness, we are beginning to question the idea of the total elimination of predators, realizing that, after all, lions, wolves and coyotes may be an exceedingly vital part of a primitive community, a part which once removed would disturb the delicate ecological adjustment of dependent types and take from a country a charm and uniqueness which is irreplaceable. To go into a region where the large carnivores are gone, to see hoofed game with its natural alertness lacking, to know above all that the primitive population has been tampered with, is like traveling through a cultivated estate. Wilderness in all its forms is what the true observer wants to see and with this realization dawns a new appreciation of carnivores and the rôle they play.

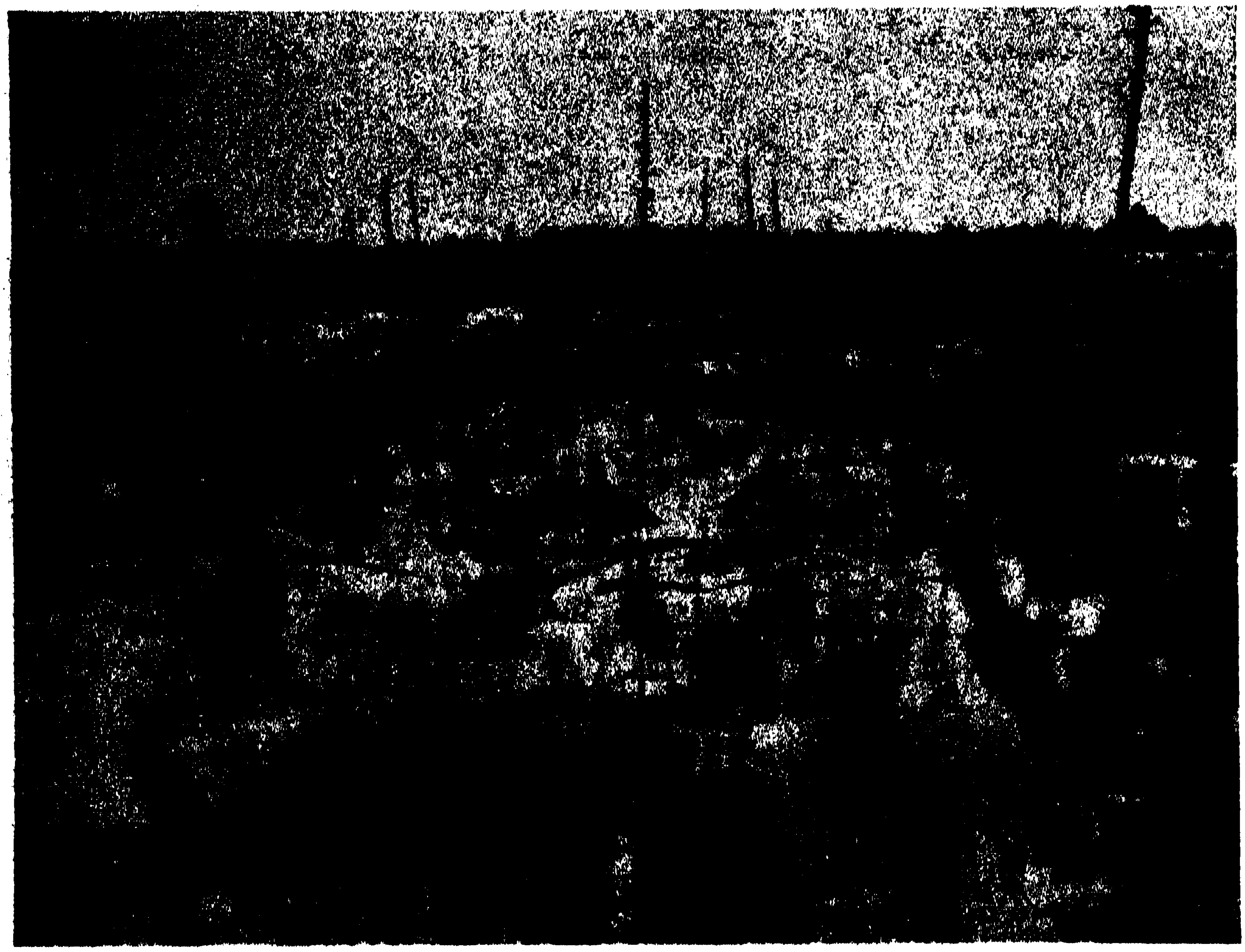
The fact that in 1928, out of tens of thousands of carnivores killed in the West, there were only eleven grey wolves recorded, that in the state of Wyoming a few years ago only five wolves were reported at large, points definitely toward ultimate extinction in those areas. In 1926 the Biological Survey reported no wolves in Arizona, and recent reports from other regions indicate a similar scarcity. In the Middle West and East, only occasionally, is a specimen recorded. In the hinterlands of Canada and in the fringe of wilderness along the northern borders of the lake states are all the wolves that are left, and at the present rate of depletion, the area encompassed by the Superior National Forest in northeastern Minnesota will soon include most of the remaining animals of the species in the United States.

Any one who has made a study of the life histories of the larger predators knows that the accusations against them are not entirely without grounds. On the other hand, it is not hard to see that many indictments are made without sufficient proof to substantiate them. It is therefore the purpose of this paper to bring out a few outstanding facts regarding the life habits of one of the largest and most maligned of the predators, the timber

wolf of the north (*Canis nubilus* Say), in the hope that some day accumulating evidence may grant it the protection and sanctuary which other forms of life now enjoy. I shall also contend that a large wilderness area may harbor a carnivore population without danger of annihilation to hoofed game and that the constant presence of such large animals of prey as the timber wolf may actually prove of benefit to the herd.

All investigations have been carried on within the boundaries of the Superior National Forest, a comparatively primitive area, where the deer (*Odocoileus virginianus borealis* Miller), and the moose, (*Alces americana americana* Clinton), are present in fairly large numbers. Although predatory animal control has been exercised for a number of years, it has been done in a rather haphazard fashion and with no great diminution of the species in question. Natural conditions prevail over much of the area, so that observations recorded should give a true picture of predatory relationships in an undisturbed situation. A great many observations are the result of a long time study not only by the author but others who are familiar with wilderness conditions. These are conclusions arrived at after many years of experience in the north, unfortunately not always from carefully kept notebooks, but rather in many cases as general conclusions based on personal deductions. This applies to a good many of the points made in the paper under discussion. The writer's experience in this particular region covers roughly the period from 1920 to the present. During this time he has covered thousands of miles, by canoe, on snowshoes, on foot and by airplane, and feels that he knows the country fairly well. The conclusions drawn are based on incidents and observations, which, had he kept a careful notebook, would be easy to cite, but like those of most other woodsmen, they are the sum total of experiences and general working

SCATTERED ASPEN (*POPULUS TREMULOIDES*)
AND JACK PINE (*Pinus banksiana*) ON THE NORTH BANK OF THE KAWISHOWA RIVER, A FAVORITE FEEDING GROUND FOR DEER IN THE EARLY SPRING. APRIL 1931.



BARREN BURNED OVER AREA NORTHWEST OF DEADMAN'S PORTAGE ON THE KAWISHOWA RIVER.

NOTE SPARSENESS OF VEGETATION IN FOREGROUND, SCATTERED CLUMPS OF ALDER (*Alnus incana*) AND HAZEL (*Corylus rostrata*), ALSO THE MUCH HEAVIER VEGETATION IN GULLIES AND RAVINES. THIS IS AN AREA OF DEER CONCENTRATION IN THE EARLY SPRING AND LATE FALL. AT TIME PICTURE WAS TAKEN, MARCH 1930, THERE WERE AT LEAST 20 DEER IN THE AREA SHOWN.

knowledge for which it is impossible to cite authority accurately. The best the writer can say is that they represent what he considers his most accurate judgment of the problem involved.

General Survey of the Superior Area[1]

The Superior National Forest lies in the northeast corner of Minnesota and is bounded on the north by a similar *region*, the Quetico Provincial Park of Ontario and on the south by the north shore of Lake Superior. Both areas, including approximately four million acres, are timber and game preserves, and inasmuch as the country is largely inaccessible, except by canoe in the summer and dog team in the winter, it is comparatively free from molestation. All population figures have been based on the approximately 2,500 square miles of wilderness south of the Canadian border.

The general topography is rough, rocky and well glaciated. The vegetation is largely second growth northern coniferous forest, interspersed by areas of the original white pine (*Pinus strobus*) and red pine (*Pinus resinosa*) climax. Fires have swept certain parts repeatedly and the resulting young growth of aspen and birch has been particularly favorable as feeding ground for deer and moose. Intersecting the entire region are thousands of rock-bound lakes and streams, all connected in a vast labyrinthian waterway. The general drainage is

[1] Based upon personal observations entirely, 1920 to 1936. Area figures from the U. S. Forest Service and State Conservation Department.

either to the north and west into the Lake of the Woods and Hudson's Bay, or south into Lake Superior. It is one of the few areas of its type still undeveloped and becomes therefore of great ecological importance. With the exception of the caribou (*Rangifer caribou* Gmelin), which migrated to the north forty years ago, together with the wolverine (*Gulo luscus* L.) and the pine marten (*Martes americana* Turton), there is little change in animal types since the days when the voyageurs of the Hudson's Bay Company traversed the waterways in quest of fur.

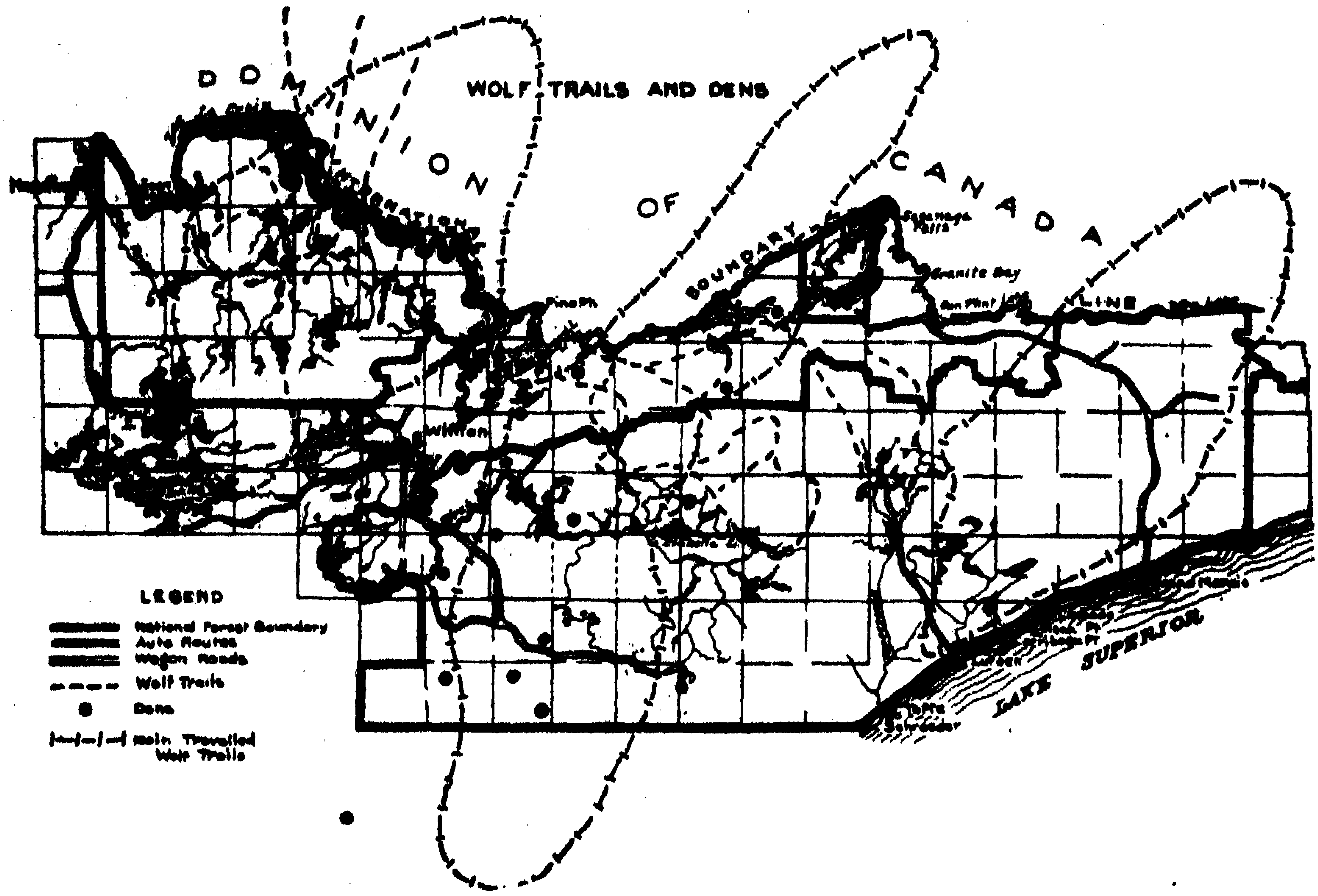
Survey of the Wolf Population[2]

It must be remembered that the wolf population is a shifting one and the very fact that the Quetico Provincial Park of Ontario lies immediately north with an open boundary of over a hundred miles in length, makes it very difficult to lay down any definite figures as to exact or permanent numbers. Wolves have runs of from twenty to a hundred miles in length, and shifting back and forth across the border, as is their wont, makes it often difficult to decide just where a certain pack belongs. Another factor which must be considered is their constant following of the deer herds from one area of big game concentration to another. Hence, the observations and conclusions given here have necessarily been arrived at over a period of years and every allowance for inaccuracy due to the above factors has been taken into consideration. However, though the figures must be

[2] Wolf populations were reported as follows: 1930, William F. Hanson, game warden, 350 wolves; 1931, Thomas Denley, forest ranger, 228 wolves; 1930, Superintendent John Jamieson, of Quetico Park, 62 wolves for the Quetico; 1929, Jack Linklater, Hudson's Bay trapper and warden, 250 wolves.

TYPICAL SPRUCE BOG HABITAT.

NOTE THE ISLANDS OF SPRUCE IN MIDDLE FOREGROUND, JACK PINE RIDGE AT RIGHT. VEGETATION IN FOREGROUND, ALDER, WILLOWS (*Salix sp.*), DWARF BIRCH (*Betula pumila*), AND HEATH PLANTS. A FAMOUS DEER TRAIL CROSSES THIS BOG. STONEY RIVER COUNTRY, NOV. 1932.



HUNTING ROUTES OF WOLF PACKS.

approximate, they are sufficiently correct to establish the contention of this paper.

My personal observations and those of government rangers, hunters and trappers, points to a present wolf population of about 250 animals or one to every ten square miles of the area under consideration. This figure is not uniform for the entire region and is entirely dependent upon the concentration of game. It can be said, however, that the number of wolves increases in direct proportion to the herbivore population.

In view of the above estimate, it may be interesting to compare the conclusions of Ernest Thompson Seton and Vernon Bailey. According to their figures, the original primitive wolf range on the continent was approximately 7,000,000 square miles. Over this territory were distributed about 2,000,000 animals or one to every three and one half square miles. The wolf population as late as 1908 was estimated at 200,000 for North America, of which only 2,000 were to be found in the West, their former stronghold. That was a quarter of a century ago, and inasmuch as killing has gone on apace since then, it is reasonable to assume that only a fraction of that number exists to-day. Of the 200,000 mentioned in 1908, half were relegated to the hinterlands of Canada or one to three square miles, and half to the United States or one to seven square miles of the remaining range. A recent estimate from Algonquin National Park of Ontario, east of the Quetico-Superior area, gives the wolf population as one to four square miles.

There are, unfortunately, no early records for the Superior Forest Area, but it is doubtful if the original population figures of one to three square miles would have held for this region. When we consider that the moose and caribou occupied the country prior to its logging some thirty to forty years ago and that they as species were not nearly as numerous as the deer of to-day, it is a safe con-

jecture that the wolf population was perhaps not higher than one to five square miles or twice the present estimate.

Hunting and Feeding Habits of the Wolf

The entire problem of predatory relationship is based upon the food habits of the carnivores concerned. This is the phase of life history which determines whether or not a species is an acceptable member of any society. Certainly, the most often voiced complaint against the timber wolf is that it is a killer of deer, and that there is a certain amount of truth to this contention stands without question.

The major portion of the food of the wolf[3] during the summer months is grouse, woodmice, meadow voles, fish, marmots, snakes, insects and some vegetation. In fact, almost anything that crawls, swims or flies may be included in its diet. During the winter months, when most of the small animals are in hibernation, the wolf is forced to feed almost entirely upon deer and the snowshoe rabbit (*Lepus americanus* Erxleben). The wolf is never a consistent and regular feeder and can go for long periods without food. When food is scarce, as it often is in the north, three or four meals a month will keep him from starvation.

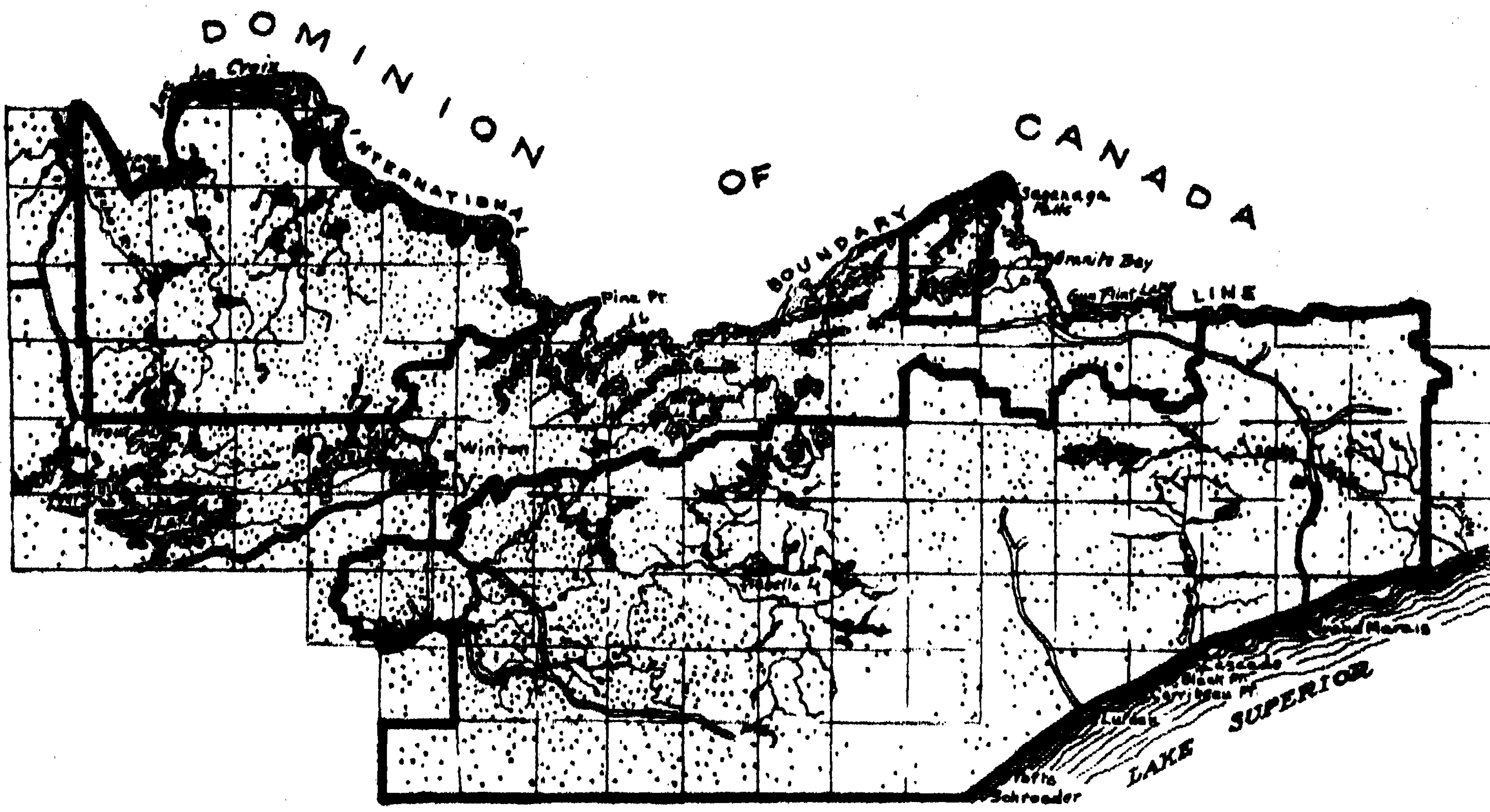
ABOVE: READING FROM LEFT TO RIGHT, SILVER FOX, RED FOX, TIMBER WOLF AND COYOTE, ALL POISONED IN WOODS LAKE AREA, FEBRUARY, 1927. BELOW: DEER CARCASS FOUND NEAR THE WEST SHORE OF SNOWBANK LAKE, MARCH, 1931. NOTE THE WELL-PICKED BONES.

Close students of wild life in the border country all agree that wolves kill comparatively few deer, and then only in the late winter and early spring periods. While there are instances of individual killers, both in the north and the west, who have slaughtered large numbers of deer, moose or elk during the course of a winter, it is no more true to say that these isolated instances are the normal feeding and killing habits of wolves as a species than it is to say that because a man runs amuck his behavior is an index for the rest of his kind. Like all omnivorous types, the wolf prefers variety in his diet and only takes the big game trails when driven to it by the scarcity of the normal food supply.

The actual hunting habits[4] of wolves are dependent upon the terrain and inasmuch as the Superior Area is such a heterogeneous mixture of widely diversified habitats, each having its own particular influence not only upon the game

[3] Food of the wolf is based upon personal observations. Stomach contents of wolves, 1929–1930 winter: 14 carcasses; reports from Jack Linklater, 1920–1930; Tom Denley, 1931.

[4] Hunting areas are based upon personal observations, 1920–1936; Jack Linklater, 1900–1930; Thomas Denley, 1900–1930; Charles Lainey, 1930; William Hanson, 1920–1930.



DISTRIBUTION OF DEER.
DENSITY OF DOTS INDICATES RELATIVE ABUNDANCE.

population but on the methods of hunting, it is imperative that we survey the region from this angle.

Virgin stands of pine shelter little game and are unimportant from the standpoint of hunting and food. There is only one exception to this type of habitat and that is the dense stands of Jack pine (*Pinus banksiana*) which deer and moose often frequent during winter storm periods. Such areas are literally criss-crossed with game trails, and wolves in their hunting follow them continually in an effort to drive their prey out into the open.

The greatest game producing areas are the mixed stands of aspen and birch which have grown up either after logging operations or fires. The bulk of the vegetation of the Superior Forest is of this type, interspersed with scattered white spruce, dense thickets of balsam and second growth white and red pine. Here is the ideal feeding ground for deer, for in a predominantly deciduous growth of this type there is always an abundance of herbaceous material, as well as shrubs and young saplings upon which they can browse. The rolling timbered ridges, swamps and swales, beaver flowages, brush-grown gullies and ravines not only furnish excellent cover and protection but food as well, and here is the maximum game population. The network of game trails traversing areas of this type are the logical starting points for the hunting activities of the large predators.

The open country which has been logged and burned time and again is of particular interest because of the dense growths of spruce, cedar, alder and willow in the creek bottoms and gulleys between the barren ridges. Deer, feeding in the open, always seek the bottom lands during part of the day, and it is here that the wolves make their most successful drives. During the late fall and early spring, the open ridges are important feeding grounds, as they remain free of snow longer than the timbered regions and become exposed considerably earlier than the valleys.

The great spruce bogs and swamps are of no great influence unless they happen to lie in between good feeding areas. Occasionally during heavy snows, both deer and moose yard up in such places for short periods, but food is never plentiful

enough so that they remain very long in one location. Cedar swamps, however, play a very important part in the winter feeding of big game animals. Deer especially congregate in such areas not only for the excellent protection they afford, but for the cedar twigs upon which they browse. Between late December and April when the snow is often very deep and ordinary food practically inaccessible, one can always find deer in such locations. In fact, during such periods, deer have been known to become so partial to this food that they preferred it to tame hay distributed by wardens of the Conservation Department.[5] Wolves on the hunt often attempt to drive such yarded animals out into the deep snow for slaughter but are seldom successful. In working such a ruse they are forced to exercise great caution, for once a wolf is caught in the well-trampled trails of the yard there is little chance to escape the sharp hoofs of its intended prey.

The many barren, meandering ridges of rock are of no significance from the standpoint of game, but they do play an important part in the technique of hunting. A cruising wolf will run along the crest of one of these open ridges, nose in the wind, keeping watch over the surrounding country. When he tires, he will often curl up to rest on some outstanding promontory where nothing will escape him. Packs have important passes and crossing places on these dividing ridges where they not only meet but leave their scent. It is from such elevations that leaders call the members of their packs together, and it is here that many hunts begin.

When the lakes and streams freeze over, they become at once a highway for all forms of wilderness life, and it is here that most of the kills are made. Usually wolves follow the shore from which the wind is coming, investigating at the same time any bays which might shelter game. When the wind informs them of game inland, they leave the lake shore immediately. On the rock ridges they stay close together, but in the valleys they spread out fan like, covering the ground systematically. The instant a deer is started, they try to force it back onto the smooth glare ice of the lake, where it will lose its footing and be easily dispatched. Often a deer will, in spite of their efforts, force its way back into the timber and then it becomes a test of speed and endurance. If the snow is not too deep or the crust too heavy, the deer have little to fear and can usually outdistance their pursuers. Occasionally, if conditions are right, a small pack will work the relay system of hunting and in some instances actually use the strategy of ambush. There are as many different ways of hunting and killing as there are situations which arise in the process. Wolves, like all carnivores, are adaptable and have a certain amount of inherent cunning which is brought into play to combat the natural obstacles which stand between them and their food. Pack leaders are those individuals which have demonstrated repeatedly their ability to provide their followers with game.

Perhaps the favorite hunting grounds for all wolves are the fringes of swamps. These alder-grown grassy margins are alive with mice, voles and rabbits, and can always be depended upon to furnish something in the way of food. Single wolves or pairs most often frequent such small game areas. Packs seldom include them in their foraging, as they are out for bigger game. Lake shores and the borders of creeks and brushy gullies come under this category. It can safely be said that outside of the movements of the packs themselves during the winter season, most of the actual hunting of the wolf family is done in such locations within easy range of their dens.

[5] Personal observations, 1936, Mud Creek Swamp, Twin Lakes Swamp. Byron Carlson, 1936, Mud Creek, Ely Buyck Road. State Game Warden.

Organization and Range of the Pack[6]

Packs vary in number from five to thirty, the smaller group being by far the most common. A pack of eighteen was seen on the Stoney River in 1918 (Denley) and one of twenty on Crooked Lake in 1922 (Linklater). Less than six is usually the case. These small packs, most often seen crossing the open lakes in midwinter, represent as a rule a pair of old wolves and their surviving pups. Wolves sometimes kill big game while hunting alone, but most of the actual killing is done either by the members of last season's family or, in the case of large packs, by several families which have banded together.

Such hunting units may travel from twenty to forty miles a day and are sometimes found as far apart as Knife and Crooked Lake, a distance of thirty miles, on consecutive days. Ordinarily, they have a beat which they cover every two or three weeks and a trapper who knows the route of a pack can bank on the possibility of its appearance in a certain locality regularly. The method a trapper employs in determining the route of a pack usually runs along the following lines. While trapping in a certain area he will probably see the trail of a pack leading over a ridge. He will then follow it for a number of miles over lakes and through valleys. For some three weeks not a sign of a wolf will be seen, but then he will suddenly find them back over approximately the same trail. When he finds this repeated for several years with very little variation, he will naturally assume that such a trail is an old one and part of the pack's hunting habit procedure. He will later find, to his satisfaction, that the same identical pack circled some ten miles away to the west, and by further checking with observers in the north and south he will discover that his route lies in almost perfectly with that of the observers. Then he has reasonable proof of the existence of one of the circular routes designated in the map. It is sometimes necessary to correlate the observations of several men in order to tie in a pack route, and although there is some room for conjecture (as there always is in determining game and predator behavior), such information is in the author's opinion as scientifically sound and based on observable fact as anything that could be worked out in a laboratory, the only difference being that here the laboratory is too big to enable easy checking.

Once the route of a pack is known, its members can be trapped quite easily as they use the same old trails in crossing rocky ridges and swamps, frequent the same coverts of game, and in every instance show a decided preference for familiar terrain. One such pass over the summit of a great divide just south of the Kawishowa River has been trapped steadily by one lone trapper for years (Denley). Every three weeks the pack returns, always crossing the same identical spot on the trail that they have used for generations.[7]

Game wardens during the month of January, 1933, (Hanson) counted twenty-four separate wolf tracks traveling north toward the Canadian border between Ramshead and Agnes Lake within a distance of three miles. Some

[6] Organization and range of pack are based upon:

		No. in pack
Denley	—Stony River, Superior Forest,	1918—18
Linklater	—Crooked Lake " "	1922—20
Personal	—Snowbank Lake " "	1926— 7
"	—Big Lake	1927— 5
"	—Basswood and Knife	1928— 8
"	—Burntside	1927— 4
"	—Kennedy Lake	1921—20
"	—Kawishowa River	1929— 9
Joe Kroll	—Lac La Croix district	1930—24

[7] Trails and range of pack are based upon: Linklater, Crooked-Knife, 30 miles, 1920; Thomas Denley, Kawishowa and Stoney District, 1930; William Hanson, Basswood district; Personal, all regions.

were evidently traveling alone, others in groups of five to eight, all perhaps members of a large loosely organized pack running its accustomed route into the Quetico region to the north. In the Superior Area there are a number of these definite cruising trails, and each winter if conditions necessitate the organization of packs for more efficient hunting, the old members guide the new over the well-known routes.

The course a pack travels is in the shape of a great, uneven circle, the diameter of which is often thirty to fifty miles. The extent of the run depends on the supply of game. If game is plentiful, the circle may be small, if scarce, it may be several hundred miles in length. The fact that hunting is always easier in a region which has been undisturbed for several weeks may account at least partly for the great range of some of these hunting trails.

Storage Habits[8]

During the period when the pack is moving there is abundant evidence that more deer are killed than it will consume immediately. It is through this habit that the wolf brings upon itself condemnation, for it gives the impression that the members of the pack do not kill for the express purpose of food, but rather to satisfy the blood lust of the race. Each winter usually produces news stories of such killing, abundantly illustrated with pictures of mutilated carcasses of deer or moose. There is hardly a lake of any size in the Superior region which has not at least one carcass to its credit, and some of the larger bodies of water, such as Basswood, Vermillion and Lac La Croix, usually have quite a number. This evidence, to the casual observer, is conclusive that the timber wolf kills more than it needs during periods when food is plentiful and easy to get. Such adverse publicity is responsible for most of the clamor for additional predatory control.

Investigation, however, convinces the unbiased observer that such killing habits are purely storage acts, even though a number of deer may be left where they fell, with no evidence of feeding upon them or of any attempt to return later for that purpose. The habit of storage is deeply seated in all carnivores and is one of the primary laws of survival. There is no reason to suppose that the wolves of the Superior Area have suddenly varied from an age-old custom and kill to-day for an entirely different reason.[9]

The failure to return to their kills can only be explained by the many years of poisoning and trapping which have made them suspicious of every old carcass, even of the animals they have brought down themselves during the course of normal hunting. In other words, wolves kill instinctively as an act of storage and would return to their kills, had not experience instilled in them a fear of every carcass that has turned cold. During the heat of the chase, the old habit of slaughter for storage purposes asserts itself, and as a result many kills are made to-day which are not used. Passing by these same kills a night later, wolves, instead of feeding as they might be expected to do, often give them a wide berth, inhibited no doubt by past experience with poison and trap.

Under primitive conditions of sanctuary, in areas where man has not made his activities felt, it is reasonable to assume that wolves would return to kills sometime during the winter. The fact that very often they are trapped or poisoned by the use of old carcasses substantiates this belief. I am confident that if an area containing a normal population of deer and wolves was left unmolested for a long

[8] Storage facts are from personal observations; Thomas Denley, 1929–1930.

[9] Storage facts based upon miscellaneous trapper information, personal observations, 1920–1936.

period, evidence would soon accumulate, indicating that the wolves were returning regularly to their kills. Ability to do this without the danger of being caught or poisoned would soon restore the normal situation in which they would not kill more than needed. At the present time there is no question but that a ranging pack on the hunt, due to the fact that kills are not always utilized, creates an abnormal situation in which there is more actual loss of game than would be the case under conditions of equal sanctuary for both predators and herbivores.

Evidence as to Actual Kill of Deer

During the winter of 1914, two timber cruisers, in a very careful survey extending over a period of six months, counted 47 deer carcasses in a 60-square-mile area of game concentration in the Bear Trap River valley (Linklater). During the spring of 1931, 42 carcasses were counted in the Moose-Newfound area of approximately the same size (Hanson). Other similar areas, checked from year to year, also in regions of relative game abundance, point to the general conclusion that nowhere is the kill more than one deer per square mile and a quarter.[10]

The real wilderness region of the Superior National Forest which this study covers, as has been stated, is approximately 2,500 square miles in extent. If the estimate of one deer per $1\frac{1}{4}$ square miles held true for the entire region, the total kill by wolves would not exceed 2,000 animals annually, it being assumed that very few if any deer are taken during the warm months of the year. Because of the fact, however, that hundreds of square miles during the snow months are practically barren and devoid of any game and that the above estimates of kill were all made in areas of game concentration, it is evident that 2,000 is too high a figure. A total kill of 1,500 deer would be within reason. If the wolf population is 250 animals, the kill per wolf would be six deer per year or one deer every two months.

Deer and Moose Populations

In order that the relationship between the timber wolf and the herbivores be understood from the standpoint of the influence of one form upon the numbers of the other, it is now necessary to arrive at an approximate figure as to the actual resident population of big game animals in the Superior Area. As has been intimated, in new and freshly logged or burned country, such as large sections here represent, browsing conditions are particularly favorable for the propagation of deer. In view of investigations which have been carried on elsewhere on the carrying capacity of forests, the wilderness area could support roughly 35,000 animals, were it not for the climatic factors of snowfall and the consequent loss of browsing opportunity. Any worthwhile estimate of game-carrying capacity must be based not on seasonal capacity but must cover the entire year. In view of the fact that much of the food is unavailable for five months of the year in northern Minnesota and that great areas during the winter season are therefore not only barren but devoid of protection from storms, it is safe to say that the carrying capacity of this area would not be much more than 20,000 animals. From a variety of independent estimates by local authorities, substantiated by personal observations extending over a period of years, the figure of 20,000, or one deer to 80 acres, seems reasonable. Moose are estimated as close to 1,000 or

[10] Storage count and evidence of kill are from: Matt Wiirimaa, Jack Linklater, Agnes Lake district, December to March, 1914, 47 carcasses, 6 townships; Gay Gilbertson, warden, Newfound Lake Area, December to April, 1931, 42 carcasses, 6 townships; J. M. Walley, superintendent of Chippewa National Forest, January, 1930, 1 carcass to 9 square miles; R. A. Zeller, superintendent of Superior, very few, only 200 carcasses reported, 1930.

one to 1,600 acres. Figured in larger units, it amounts to 8 deer per square mile and 1 moose per 2½ square miles.[11]

In order to attain a relative idea of the big game-supporting capacity of this region as compared with other somewhat similar areas, it may be interesting to mention the observations of others. Dr. C. A. Schenk advocated limiting the number of deer in the Southern Appalachian Forest to one to 166 acres. In Pennsylvania to-day, Henry E. Clepper states that the average carrying capacity is one deer to forty acres. In Europe, where browsing conditions are entirely different from those found in the United States, it is the consensus of opinion of gamekeepers and foresters that it takes from forty to fifty acres to support a deer the year round. Surveying all figures and estimates available, the average of one deer to every fifty or sixty acres seems to be the most common. The Superior Area with its young and vigorous mixed deciduous growth could therefore support a greater deer and moose population than it actually does, were climatic conditions entirely favorable.

General Conclusions

Proponents of predatory animal extermination base their claims on the numbers of big game animals sacrificed every year as food. To combat and refute these claims it must not only be known how many deer and moose are killed, but how great a drain a herd can stand without serious diminution of its breeding stock. It becomes then a problem in which one set of figures is balanced against another, a problem in which the burden of proof is placed upon those who believe that predators have their place.

Since the total deer population of the Superior Area is in the neighborhood of 20,000 animals, and as authoritative research has estimated they can stand a drain of 20 per cent. without diminution of adequate breeding stock, it means that the deer herd could stand an annual loss of about 4,000 animals. Inasmuch as the deer and moose populations seem to be holding their own and in many parts of the forest actually increasing, it may be inferred that no more than this number are being lost each year. It may also be assumed that at least half of this number can be accounted for either because of old age, disease or the fact that a large number are either killed or wounded as they stray beyond the refuge lines during the biennial hunting season. It has been estimated that wolves are directly responsible for some 1,500 deer killings annually, which comes well below their share of the possible 20 per cent. drain.

Those who hold that wolves will soon mean the complete extermination of deer and moose are still influenced by the oft-quoted estimate that each wolf kills a deer a week. If this were so, and if the wolf population is 250 animals, as estimated, they would exact at that rate a toll of 1,000 deer per month or 12,000 per year, 60 per cent. of the total herd, an absolutely untenable figure.

The presence of the timber wolf in the Superior Area, instead of being a hazard, is a distinct asset to big game types. Long investigation indicates that the great majority of the killings are of old, diseased or crippled animals. Such purely salvage killings are assuredly not detrimental to either deer or moose, for without the constant elimination of the unfit the breeding stock would suffer. Furthermore, the wolf is a natural stimulus to a herd's alertness and injects the primitive element of danger without which most big game animals lose much of their natural charm.

Large wilderness areas such as the Superior Forest demonstrate that sanc-

[11] Deer and moose populations are from personal observations, 1920–1936, collaboration with the above observers and many others over a period of years.

tuary can be successfully given to both herbivores and carnivores without danger of decimation of the big game types. The timber wolf is an integral part of the wilderness community, the destruction of which would destroy the fine balance between related forms. To eliminate as vital a relationship as exists between predatory forms and the animals they prey upon, to destroy a mutual dependence, means that artificiality has entered the wilderness picture.

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LITERATURE CITED

Adams, Chas. C.
1925. *Roosevelt Wild Life Bull.*, 2: 4, February.
1925. *Jour. Mammal.*, 6: 2, May.
1930. *Jour. Mammal.*, 2.
Anthony, H. E.
1931. *Science*, September 18.
Bailey, Vernon
1908. *Biol. Survey Bull.*, Circ. No. 63.
1907. *U. S. Dept. of Agr. Forest Service Bull.*, 72.
Clepper, Henry E.
1931. *Penn. Dept. of Forests and Waters Bull.* No. 50, 1–43.
Criddle, Norman E.
Can. Dept. of Agr. Bull. 13, 1–24.
Dice, Lee R.
1925. *Jour. Mammal.*, 8: 1, February.
Goldman, E. A.
1925. *Jour. Mammal.*, 6: 1, February.
Hearings, Congressional
1931. *Comm. on Agr. and Forestry*, Bill 3483.
Howell, A. Brazier
1930. *Pub. Am. Museum Nat. Hist.*, May.
Leopold, Aldo
1931. "Game Survey of the North Central States," American Game Assoc., Wash., D. C., 189–226.
Newson, W. M.
1926. "The White Tailed Deer," 1–284. Scribner and Sons, N. Y.
Merriam, C. Hart
1908. *Biol. Surv. Bull.*, No. 63.
Shelford, V. E.
1926. "Naturalists' Guide to the Americas," 267–284. Williams and Wilkins, Baltimore, Md.
Schenk, C. A.
1909. "Forest Protection."
Seton, E. T.
1929. "Lives of Game Animals." Doubleday Doran and Co., N. Y.
Taylor, Walter P.
1922. *Jour. Mammal.*, 5: 1.
Walker, Ernest P.
1928. *Jour. Mammal.*, No. 3, August.

SHELLFISH FOR FOOD

By Dr. LOUISE M. PERRY

SANIBEL, FLORIDA

> She is neither fish nor flesh nor good red herring.
>
> —JOHN HEYWOOD

> That man had sure a palate covered o'er
> With brass or steel, that on the rocky shore
> First broke the oozy oyster's pearly coat
> And risked the living morsel down his throat.
>
> —JOHN GAY

FROM times before history began man has known the value and probably appreciated the flavor of shellfish as food. Ancient kitchen middens found near the seacoasts in many parts of the world from Sweden and the Aleutian Islands to Tierra del Fuego and Tasmania, where middens are still accumulating, are made up mainly of the shells of molluscs eaten by men of the Neolithic Age, who cast the empty tests upon these refuse heaps along with the bones of fish, birds and mammals.

Through centuries of advance toward established civilization, man has adapted to his use and introduced into cultivation many plants and animals which were quite unknown to his forbears as possible sources of food. Opportunity of choice and superabundance of supply have developed a taste both discriminating and exacting in its demand for variety and flavor and an appetite stimulated beyond the requirements of need. The time-honored method of trial and error has eliminated a good many items from the modern table d'hôte which less critical tastes considered dainty and delicious. The years are long since eggs of ants and the fat, white larvae of beetles were generally regarded as tidbits for honored guests and favored chieftains; still longer are the years since a hungry hunter along some ocean beach found and ate his fill of a "Whale that died and foundered after a month at sea," and soon thereafter wondered why the gods had visited him with a painful affliction.

Living races all over the world to-day use for food the molluscs of their seacoasts and estuaries, their rivers and even their forests and fields. Molluscan prestige has increased with growing appreciation of the succulent quality and unique flavor of shellfish which have traveled in an artificially arctic atmosphere far from their native habitats. Sophisticated society restricts the use of molluscs as food to a few established favorites; many other equally deserving varieties, from unfamiliarity alone, are repugnant to all but the initiate. Travelers to the Orient and less far afield sometimes try a salad of conch, a stew of squid and the novel bonne bouche of "escargots" steamed in their shells and offered with a delectable dressing of garlic-seasoned mayonnaise. In some remote parts of the world where the food balance between necessity and supply is always precarious, the native molluscs of land and water help to maintain a margin of safety as to quantity and an essential element of quality.

Throughout the whole South Seas the octopus and the squid are hunted and captured for food. Native fishermen with poised spears wade along the coral reefs peering through the clear water for an octopus partly hidden in his lair. The spears are thrown with marvelous accuracy, and usually with results wholly satisfactory to the fishermen. Among the Fiji and Melanesian Islands and in the Moluccas, where the nautilus is fairly abundant, these creatures are taken in cages not unlike the familiar cylindrical lobster pots. The traps are baited with

fish, anchored in a few fathoms of water and drawn up to be inspected each day. In Naples and Honolulu, as in Bangkok and Yokohama, octopus and squid, both fresh and dried, are regular offerings in the fish markets. From China and Japan dried cephalopods are exported to other countries to meet the demand of their oriental populations. Even faraway Newfoundland has a small export trade with the Orient in dried squid.

In the countries around the Mediterranean Sea from Spain and Morocco to the Levant, natives eat the animals of the moon shell, *Natica; Turbo,* the turban shell; *Murex,* the "purple fish" which furnished the Tyrian dye; the *Triton,* named for the sea-god son of Poseidon and Amphitrite, who controlled the waves at will by blowing upon his conch-shell trumpet; *Strombus,* the top shell; *Melongena; Cardita* and *Pholas,* the latter known in the markets as the "sea-date" or "datefish" because of its cylindrical shape. At Key West and in the Bahamas the queen conch, *Strombus gigas,* is a staple of food for man and a highly successful bait for fish. Prepared in accord with various recipes, undisguised or as an "à la," it appears on the usual menu, but its leathery quality and peppery taste do not often please the unaccustomed appetite.

West Indian Negroes collect large chitons from the rocks along the island coasts, cut off the muscular foot of the animal, call it "beef," and eat it in the natural state or compounded into a savory loblolly with vegetables and seasonings. *Pholas costata,* the angel's wing, is esteemed in Cuba as we value the Venus clam, and on many South Florida beaches the great heart clam, *Cardium robustum,* is gathered by fishermen who make from it a wholesome and palatable chowder. The herring gulls, which winter in the South, also appreciate this splendid *Cardium.* They fly high above the beaches with the heavy molluscs in their beaks, drop them to break the shells, and if the first effort is not successful it is repeated until the shell is cracked by the impact of the fall and the enterprising birds enjoy their reward of fresh, delicious sea food.

Four-footed animals of one kind and another have learned that clams and oysters are good eating. The coons of southern Florida and the Keys are so fond of the oysters that grow on the roots and submerged branches of the mangrove trees and on the reefs in shallow water that these molluscs are known locally as "coon oysters." Up in the Bay of Fundy herds of pigs used to swarm out over the flats at low tide to root for buried clams. At the turn of the tide they turned too, and ran squealing for dear life to keep ahead of the rising water.

In southern Florida and at Panama the slender razor clam, *Ensis,* and the little coquina clam, *Donax* (in size and weight one of the smallest of its tribe), are considered delicacies. The fortunate visitor to these coasts who is served with a bowl of coquina broth is introduced to a new and unique flavor. He will probably take a few cans of the broth away with him.

All along the Atlantic seaboard, around peninsular Florida and into the Gulf of Mexico, common clams of several varieties are high in popular esteem. At the North, the old Indian name "quahog" still means the hard-shelled *Venus mercenaria,* the money shell from which purple and white wampum were made, and whose small ones are the "little-neck clams," a name supposedly derived from Little Point, Long Island. The soft-shelled "manninose" is *Mya arenaria.* It has been abundant from Pleistocene times up to the present. A congenial beach station along the North Atlantic coast may be almost paved with succeeding generations of this mollusc. *Spissula solidissima* is the "surf clam" of the New

England coast, not generally liked; and its smaller southern variety is not eaten at all save by other creatures of the sea. "Cherrystone" is a name to conjure up delightful recollections of tender clams served icy cold on the half shell. In clam fritters at Wachapreague and Chincoteague, in clambakes on the Jersey coast and Long Island, steamed or in chowder, as a joy to the epicure, it is second only to the oyster.

Off the west coast of Florida, southward from Marco Pass, are the most extensive clam beds in the world; and the nearby little towns of Marco and Caxambas receive the shellfish brought ashore in bargeloads from dredges which operate a few miles off shore. These clam beds are protected by the government, and it is unlawful to take clams of less than a specified size.

On the Pacific coast enormous numbers of "sea ears," *Abalone*, are taken from their rocky habitat between high and low water marks. The animals are removed from the shells, strung on cords, dried and sold to oriental peoples living on both sides of the Pacific, while the beautiful iridescent shells are extensively used in the manufacture of souvenirs and novelties. Farther north the great clam, *Panopaea*, which passes its life buried in the sea bottom of the intertidal zone, is said to sell in the markets of Seattle at a dollar apiece. California's "flat clam" is a *Semele*, and the cold-water-loving species, *Glycimeris generosa*, is the "geoduck," an important item in the food supply of the Northwest Coast Indians.

The great *Tridacna gigas* of the far Orient, not uncommon on the Great Barrier Reef of Australia and on to the Solomon Islands, the Moluccas and the Philippines, is not only the largest of living molluscs, but it also attains to man's age of threescore years and ten. One clam will yield twenty pounds of edible flesh, and the huge bivalve shell may weigh five hundred pounds. The British Museum has two specimens of single valves which weigh respectively one hundred and fifty-four and one hundred and fifty-six pounds. The pure white, beautifully scalloped and deeply concave valves have been used in churches as benetiers for holy water—St. Sulpice in Paris has one—and as basins for garden fountains.

Whelks of the family Buccinidae are eaten as a matter of course in the British Isles, and nearly every fishmonger's shop in London and around the coast offers the periwinkle ready cooked in its shell at "tuppence the pint." Tiny cockles are steamed and served with a shake of pepper and a sprinkle of vinegar to be eaten on the spot or carried away. Great Britain's "gaper" clam, allied to the genus *Mya*, is not valued as food. Nor is the channel abalone, *Haliotis tuberculata*, the "ormer," presently consumed in the Channel Islands where it was once quite generally eaten.

Mussels are also consumed in quantities in Great Britain, but are not cultivated for market demand as they are on the French and Belgian coasts across the English Channel, where mussel farming is practiced on a large scale and by a modification of a method said to have been devised by an Irishman who was shipwrecked on the coast of France in the year 1235. He set nets attached to stakes for the capture of sea birds, but soon found that the mussels which attached themselves to his stakes afforded a more nutritious and palatable provender. Mussel culture by the "bouchot" method, as practiced to-day, has developed from Irish Walton's primitive nets and stakes. The mussels which were lifesaving food to him have become the foundation of the justly famous "Soupe au Moules."

France and some other parts of Europe have their "escargotieres" or snail gardens, where snails are bred and fat-

tened for the market. We have Pliny the elder as authority for the existence of snail preserves at Tarquinium, in Italy, about the year 50 B.C., and Pliny the younger, in his Epistles, chides a friend for going off to eat sea urchins, scallops and oysters when he had agreed to dine with him on three snails, two eggs and a lettuce apiece, with mead, snow and barley water, olives and beet-root with gourds and truffles.

Horace tells us that—

> 'Tis best with roasted shrimps and Afric snails
> To rouse your drinker when his vigor fails.

This record of practice in Horatian Rome is associated with Pliny's advice for the dose of "an uneven number of snails" as a remedy for coughs and stomachache; and with his cure for headache, which was a plaster made of decapitated slugs applied to the forehead. Belief in the efficacy of snails eaten alive and whole, or boiled in milk or wine as a prophylactic and cure for consumption, asthma, corns, ague and dropsy, persists to present times among some isolated peoples whose unfortunate weaklings are given daily doses of snails as a tonic treatment. Still more astonishing is the statement that emulsified snails have been most successfully used in the manufacture of synthetic cream!

From the England of George the Third a cure for warts, which was old even then, was brought to America, and may still be in use. A snail with a black shell must be found and rubbed on each wart separately, the while saying the magic couplet—

> Wart, wart, on the snail's shell black,
> Go away soon and never come back.

Then the snail must be placed upon a branch of tree or bush and tacked down with as many thorns as there are warts to conjure away. As the snail dies and disappears the warts will vanish. This formula was tried with full faith and confidence in the writer's little girlhood. With the help of an old colored servant a black snail was found, the warts were well rubbed, and the small girl ran round and round the house chanting the magic rune. The snail's shell was tacked with thorns to a yellow rose bush, and when the shell was empty the warts were gone and forgotten.

The tender and delicious scallop is probably more esteemed in the United States than elsewhere in the world, although its range of distribution is throughout the Seven Seas. The Gulf of St. Lawrence and the Labrador coast have the great northern scallop, *Pecten tunicatus,* peculiarly delicious but not very abundant. The Atlantic coast species is *Pecten irradians,* and in the Gulf of Mexico lives its southern congener, *Pecten dislocatus.* Both species are so much in demand that it has become profitable to substitute for the firm, shining-white muscle of the true scallop the corresponding part of some other mollusc, notably *Atrina,* and even to punch out with a specially devised instrument appropriately-sized pieces of flounder and other dry and white-fleshed fish. The true scallop is the adductor muscle of the bivalve, whose function is to draw together the two valves of the shell and maintain them in apposition. Only this muscle is used for food, all other parts of the animal are discarded. Nova Scotia's scallop industry employs a special fleet of boats and sends three fourths of its annual catch to New York City.

There is evidence that the scallop's lifespan is from two to three years. Sexual maturity is reached in a year, and one individual scallop may be responsible for more than a million eggs discharged into the water at one spawning. The eggs are spherical and measure one six thousandth of an inch in diameter.

Fresh-water shellfishes are generally

tasteless and insipid, and have never been regarded as desirable foods, except in circumstances where necessity rather than choice must be considered. The fluviatile mussel, *Anodonta edulis,* is cultivated for food in some parts of China. African natives make use of their river species to some extent, and in some of the East and West Indies the natives eat the molluscs of their streams; but the principal use man has made of fresh-water mussels is the utilization of the nacreous linings of their shells for the manufacture of buttons and other small articles of utility and beauty.

Of all the different varieties of shellfish adapted to gratify an appetite for variety and delicate flavor, the oyster stands easily at the head of the list. As long ago as the first century B.C., a certain Roman, one Sergius Oratus, cultivated oysters on a large scale as a money-making venture. His nurseries were in the Lucrine Lake, not very far from Rome, and the delicacy of his oysters was considered to be so superior that those brought from other beds in Italy, and even from faraway Britain, were put in his "vivaria" to acquire the Lucrine flavor.

Like the Lucrine beds of old Italy, certain localities in America are to-day famous for the flavor of their oysters. Bluepoints, Chesapeake Bays, Cotuits, Wachapreagues and Lynnhavens, all have their partisans who declare that their favorites surpass those of any other beds. In the far South it is believed and staunchly maintained that those oysters, which grow naturally on the aerial roots and drooping branches of the mangrove trees, when eaten freshly roasted in the ashes of a campfire, excel any Bluepoints ever served in the half shell on ice in a metropolitan restaurant.

The indigenous, small and thin-shelled Pacific oyster, *Ostraea lurida,* has only a local reputation, and has never reached the commercial importance of its Atlantic cousin. Marketable oysters are usually from planted beds, and neither the yield nor the value is very great. The anecdote of the young lady from California, who ordered two dozen fried Chesapeake oysters in a Baltimore restaurant, suggests a contrast in bulk at least.

The European oyster, *Ostraea edulis,* is native from Norway to Italy, but the market demand is almost wholly supplied from artificially cultivated stock matured in shoal waters along the coasts. French ostreiculture culminated in Normandy in the production of that special delight of the epicure, the "green oyster," whose pedigree as a delicacy without peer goes back at least to 1713, when it was served as a rare luxury at a banquet given by an ambassador to the Hague.

The British Isles have extensive oyster banks in the Thames estuary, and oyster farms at Whitstable and other places along the English coast; near Edinburgh in Scotland, and in Ireland's County Down.

The British oyster has a venerable tradition. The Piltdown men may have found it good. Men of Caesar's legions enjoyed it, and among the English of three hundred odd years ago there was a well-known and accepted proverb that "Whoever eats oysters on St. James's Day will never want money." In point of fact, the oyster-eating season in London was inaugurated on old St. James's Day, the fifth of August. Not quite in conformity with this traditional date is the record of a custom which was ancient at that time. During the first few days of the oyster season, children of the humble classes would collect the shells cast out from taverns and fishmongers' booths and build them into rude heaps. By the time of St. James's Day the little piles would be complete, with a candle stuck in the top of each, ready to be lighted at twilight and watched by the young builders, who claimed a penny from each passing stranger, professedly

to keep the votive candle burning. No doubt this is a survival of ancestral custom before the Reformation, perhaps brought from the shrine of St. Iago in Spain.

In the year 1675, during Charles the Second's reign, a certain Mr. Walter Tucker, of Lyme, Dorset, was billed and subsequently paid for:

30 lobsters	L 1	10	0
6 crabs	0	6	0
100 scallops	0	5	0
300 oysters	0	4	0
50 oranges	0	2	0
	L 2	7	0.

"Proud Preston," in Lancashire, boasted for seventy years of its "Oyster and Parched Pea Club." Records of the club for the year 1773 name among its staff of officers one called "Oystericus," to whom was entrusted the responsibility of looking after the oysters, which at that time were sent by "fleet" from London.

From April to August is the spawning time of the oyster in temperate latitudes. During this spawning period the oysters are said to be "in the milk" and are unfit for food. Here is the origin of the ban upon eating oysters during the months which do not include the letter "r" in their spelling. In the South the spawning process commences earlier in the season, but in any latitude warm weather is absolutely essential to the survival of the "spat," as the newly hatched young are called.

For a time the young oysters swim freely about, and during this stage of their lives they are a part of the drifting multitudes of tiny creatures which form the basic food of all animals that live in the seas. Very soon the little cilia, or hairs, by whose movements the young molluscs are able to swim about, are lost, and the baby oysters settle down to sedentary life, becoming firmly attached by the left, or under valve of their shells to some solid object in the water where they happen to be when this change occurs.

Their rate of growth is rapid. From microscopic smallness, within a year a diameter of an inch has been attained, and this rate of growth continues to the third or fourth year. Subsequent increase takes place more slowly, but quite roughly speaking, an oyster is as many years old as its shell is inches wide. Five years develops an oyster to its succulent best, but the natural span of life is believed to be about ten years. Reproductive activity commences about the third year, and it is estimated that each individual oyster produces from three hundred thousand to sixty million young, most of which, however, do not escape their many enemies to reach the period of maturity.

Oysters are said to grow best in muddy water and to breed best in clear water. The tidal alternations, bringing in clear water from the open sea and draining from flats and bayous water rich in sediment and organic matter, seem to provide the happy medium in which the Atlantic species, *Ostraea virginica,* attains perfection.

Not only in infancy is the oyster beset by enemies. All through life it escapes only by good luck from the attacks of starfish and of such predatory, carnivorous molluscs as the oyster drills, which play so much havoc in the oyster beds that special nets and dredges have been devised to capture these active invaders. Where oysters and mussels grow together, the oyster must wage a constant passive fight against starvation and suffocation, usually to its own discomfiture, since the beds are often smothered by the rapid overgrowth of their unwelcome neighbors. The parasitic boring sponge, *Cliona,* burrows into the oyster shells, pitting them with small round holes, and forcing any unfortunate oyster to expend all his energies toward maintaining a shelter for his soft and defenceless body.

Nor does this inventory complete the tally of creatures which prey upon the helpless oysters. Disease germs attack them, birds prey upon them, small animals and fish eat them, and man himself is the arch enemy of all.

Oyster culture in the United States was estimated at the turn of the century to have a value to growers of $14,211,713; to give employment to more than 60,000 people during the shucking season, and to produce about 26,453,146 bushels of oysters, principally for home consumption. About 40 per cent. of these oysters are from natural beds. Chesapeake Bay is the most productive area, with Long Island Sound taking second place. Baltimore is the most important center of distribution in the country, but New York City consumes the greatest quantity and has a considerable export trade to Europe.

Throughout the Japanese Archipelago, *Ostraea cuculata* thrives abundantly in natural beds in shallow and brackish water. The adjacent deep waters produce the great-sized *Ostraea gigas*. Molluscan culture both for food and pearl production has been carried to a high degree of development in Japan and is an important industry.

No one can tell an epicure how best to prepare his oysters. No less than forty recipes are contained in one very old cook book, and "The Cook's Oracle," available both in Boston and London more than a hundred years ago, has this to say:

> Common people are indifferent about *the manner of opening Oysters,* and the time of eating them after they are opened; nothing however is more important in the eyes of the experienced Oyster eater. Those who wish to enjoy this delicious restorative in its utmost perfection must *eat it the moment* it is opened, and with its own gravy in the under shell; if not *Eaten while absolutely Alive,* its flavor and spirit is lost. . . . The true lover of an Oyster will have some regard for the feelings of his little favorite, and will never abandon it to the mercy of a bungling operator, but will open it himself, and contrive to detach the Fish from the shell so dexterously that the Oyster is hardly conscious that he has been ejected from his Lodging, till he feels the teeth of the piscivorous Gourmand tickling him to death.

This seems fairly to express the opinion of connoisseurs for more than two thousand years, and the "piscivorous Gourmands" of our own time are rejoiced to know that soon they may have their oysters in the full blush of living perfection, however far removed from the seacoast they may dwell. Investigational Report No. 15, of the United States Bureau of Fisheries, by V. Koehring and H. F. Prytherch, describes a method, protected by patent, by which oysters may be narcotized before removal from their shells, and reawakened to full activity without experiencing the shock of the "shucking" process of suffering any injury to the soft parts. The oysters are anesthetized in either fresh or salt water to which has been added a small quantity of such an acid as hydrochloric or acetic. A chemical reaction with the lime salts of the oyster shells releases carbon dioxide into the water, and it is this agent which so relaxes the muscle of the oyster that the shell gapes widely. Dr. Prytherch says it may prove desirable to employ ethyl alcohol for narcotizing and opening oysters, as his investigations have shown it to be especially effective; so where the American Indian solved this problem by the use of fire, the modern oyster farmer may go him one better and employ "firewater" to facilitate removal of the live meat of this delicious shellfish.

SEX AND GENES

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SEXUALITY is one of the most fundamental and general of the peculiarities of living things. In each species of animal or plant there are produced reproductive cells of two different sorts, which have an attraction for each other, so that they come together in pairs and fuse, and out of the product of such a fusion develops a new individual of the species.

Among animals the uniting cells are known as egg and sperm, respectively. Individuals which produce eggs are known as females, those which produce sperms are known as males. Other differences between the sexes are secondary and dependent upon the primary difference, egg production or sperm production. Such secondary differences arise largely through the action of the hormones, chemical substances which are produced by the same body structures which produce the eggs or sperm and which substances profoundly affect the constitution and behavior of the individual.

In plants as well as animals there are produced two kinds of reproductive cells, which we may call male and female, respectively. In some species they are produced as in animals, by male and female parents, respectively, but more frequently in the higher plants the same parent produces both sorts of reproductive cells in the same flower; what corresponds with the sperms of animals being produced by pollen grains, and what corresponds with the eggs of animals being produced in the ovary of the flower.

But whether we are dealing with animals or with plants, there is found to exist an attraction between the male and the female reproductive cells in each species, so that they strive to unite. But as soon as this union is accomplished, the attraction ceases to exist. It is as if egg and sperm bore opposite electrical charges, one plus, the other minus. The moment egg and sperm unite, the fusion product becomes neutral.

Fertilization of sea-urchin eggs is a favorite and much-studied subject illustrating this matter, since the whole process takes place outside the bodies of the parents in sea-water and can be observed continuously under the microscope. As a sperm approaches an egg, the latter protrudes a little elevation of its surface toward the sperm, and into this the head of the sperm penetrates. Instantly the eggs loses its attraction for sperms and secretes a superficial membrane which serves effectively to exclude other sperms. The pronucleus of the egg still retains, nevertheless, an attraction for a sperm pronucleus into which the head of the sperm has metamorphosed. These two pronuclei come together within the egg and fuse, and out of this fusion nucleus, the new individual which develops from the egg derives its nuclear material and so its inheritance from its two parents in equal measure.

In the fertilization of a sea-urchin egg, as just described, we must carefully distinguish two processes of attraction between male and female elements; first, the attraction between egg and sperm which is extinguished or satisfied the moment a sperm enters the egg, or (if you prefer so to state the case) the moment the egg *captures* a sperm. Secondly, there exists an attraction between egg nucleus and sperm nucleus which is later extinguished or satisfied when those nuclei have united and intermingled their substance.

It is an alluring but possibly fanciful thought to regard these attractions as based on opposite electrical charges which are neutralized when a union is accomplished, though it may well be chemical rather than electrical differences which form the basis of the attraction. If that or something analogous to it actually exists, we can think of the sperm and the nucleus which it carries as both negatively charged, whereas the egg and its contained pronucleus are positively charged, or *vice versa*. These opposite charges serve first to bring the sperm into the egg, when the egg-sperm differential charge disappears, then to bring the two pronuclei together, after which the nuclear differential charge disappears and the fusion nucleus goes on its way to develop a new individual body.

The process of fertilization in a flowering plant may be regarded in a similar way. The male element in this case is a pollen grain produced in the anther of a blossom. Falling on the receptive stigma of a flower, it is stimulated to rapid germination. Its fungus-like pollen tube penetrates downward through the style to the ovary of the flower, its growth guided and accelerated apparently by a substance or substances given off from the ovary. It may have to follow a devious course to reach the ovary, but it does not fail to find its way to the minute micropyle which would admit it to the presence of the ovosac in which an egg cell is maturing. Again, as in the fertilization of an animal egg, one may distinguish a two-fold attraction: first, between the pollen tube and the ovosac, which is extinguished or satisfied when the two meet. There may be many pollen tubes growing through the style of the flower toward its ovary, but only one may reach each ovule, then the attractiveness of that ovule ceases, as if its positive charge were neutralized. Secondly, there is an attraction between the egg nucleus and a pollen nucleus which is discharged from the tip of the pollen tube into the ovosac. This attraction also is extinguished or satisfied by the fusion of egg nucleus and pollen nucleus to form a fusion nucleus that produces an embryo, a rudimentary new individual of the species.

In many flowering plants, what is called a double fertilization occurs. The pollen tube contains two gametic nuclei, each of which corresponds with the sperm head of an animal spermatozoon. One of them (it is apparently a matter of chance which) fertilizes an egg nucleus, as already stated, to form the embryo; the other unites with one or more other nuclei, sister products to the egg nucleus but destined not to form an embryo, but "endosperm," a reserve of food stored along with the embryo in the seed. The endosperm nucleus or nuclei of the ovosac thus have a sex attraction similar to that of the egg nucleus, and this is similarly satisfied or extinguished by union with a pollen tube nucleus. They carry the same sort of a charge as the egg nucleus and the ovary, contrary to that carried by the pollen tube and its contained nuclei. They are potential egg cells and like other egg cells have an affinity for male gametes of the species.

The affinity between egg and sperm is not restricted to the gametes of a single species. The eggs of one species attract and may unite with sperms of a different species. This shows that the nature of the differentiation of male from female is the same in different species. Male gametes in different species behave as if they all carried a negative charge which gave them an affinity for all positively charged or female gametes.

When the egg of one species is fertilized by a sperm of a different species and thus produces an embryo, we call such an embryo a hybrid, and it partakes of the properties of both species. Such hybrid offspring are frequently vigorous but commonly sterile. More often they are incapable of survival. The more distant the relationship between the species crossed, the less likelihood is there that

offspring capable of survival will be produced.

Two species of rat sometimes reared in captivity, the Norway rat, best known in the tame white variety, and the so-called Alexandrian or black rat, can with difficulty be crossed. Hybrid embryos are produced which, however, survive only through about half of the normal gestation period, then perish. No living hybrids have ever been produced experimentally.

Mouse and rat, less closely related, are assigned at present to different genera, and no hybrids between them, even in the early stages of development, have been produced, although several investigators have attempted to produce them.

Many years ago, in the early days of Mendelism, I published an essay on the heredity of sex, in which I advanced the then novel idea that sex is inherited in accordance with Mendel's law, like other characters of animals and plants. I supposed that the attraction which exists between an egg and a sperm was due to what we should now call their sex genes, and that only such unions would occur as brought together contrary sex tendencies or determiners. It was suggested that all diploid individuals (products of fertilization) were thus sex-heterozygotes which had inherited maleness from one parent, femaleness from the other, and would in turn transmit each of these in half of its gametes.

Thus there would be eggs transmitting maleness and other eggs transmitting femaleness; and also sperms transmitting maleness and other sperms transmitting femaleness. But only heterozygous unions would occur, since a male egg would not attract a male sperm, but only female sperm, and *vice versa*.

This hypothesis proved to be only half true. There are indeed species, like the fly Drosophila and the mammals in general, in which sperms transmit, half of them femaleness in an X-chromosome, and half of them maleness in a Y-chromosome, but in these same species *all* eggs transmit femaleness in an X-chromosome, which is contrary to my hypothesis that both sexes are sex-heterozygotes.

There are other species, such as the moths among insects and birds in general among the vertebrates, in which eggs transmit half of them femaleness in an X-chromosome and half of them maleness in a Y-chromosome, but these same species transmit in their sperms only maleness in a Y-chromosome, which again is contrary to the hypothesis that both sexes are sex-heterozygotes.

The truth is that we must distinguish between the *sex reaction* of a gamete and the *sex gene* which it transmits. The two may or may not be alike. All sperms are, in reaction, male gametes and are attracted by female gametes, eggs, but in the case of mammals only half of the sperms *transmit* a male sex gene, the other half transmit a female sex gene. On the other hand, the eggs of mammals which in their sex-reaction are female regularly transmit also a female sex-gene. Thus the offspring of mammals are some of them male, some of them female in their sex-reaction as individuals and in the sex-reaction of the gametes which they produce, but in the sex-genes which they transmit in those gametes, sperms are of two sorts, male producing and female producing, respectively, whereas all eggs are female producing.

My original hypothesis, that sex inheritance is Mendelian, has proved correct as regards one important feature of Mendelian inheritance, dominance. When a sex heterozygote is produced, one in which contrary sex tendencies are united, the character of one sex dominates, to the exclusion of that of the other. Thus in Drosophila and mammals the sex heterozygote is a male, that is, has a male sex-reaction and produces sperms, maleness being dominant, femaleness recessive.

On the other hand, in birds and moths,

femaleness dominates in the heterozygous sex, which is female in sex-reaction and gamete production, maleness being recessive and expressing itself only in homozygotes, males.

The two radically different systems of sex determination found among animals are thus seen to differ fundamentally in the matter of dominance, *i.e.*, as regards the relative strength of the sex genes. In mammals maleness is dominant, and the genetic determination of the sex of offspring rests with the sperm; in birds femaleness is dominant and the genetic determination of the sex of offspring rests with the egg.

Among fresh-water fishes, both systems of sex determination occur in different species of the same genus, and it is possible to cross these. An instructive study of reciprocal hybrids within this group has been made by Dr. Bellamy on the Los Angeles campus of the university. He crossed *Platypoecilus maculatus* in which femaleness is dominant with *P. variatus*, in which maleness is dominant. Using the female of one species in making the cross, offspring of both sexes were produced. Using the female of the other species, only male offspring were produced.

The cross which produced only male offspring was made between the sex-homozygotes of both species. Using X to designate female sex-gene content and Y to designate male sex-gene content, we may express this cross thus:

♀ parent (egg producer)	♂ parent (sperm producer)
XX	YY
eggs all X	sperms all Y

The zygotes which result are all XY and *male*, maleness dominating and thus indicating male dominance to be the rule when the special strong genes of each species are not present.

In the reciprocal cross both parents were sex-heterozygotes, maleness being dominant in one (the male parent),

	♂ parent (sperm producer)			♀ parent (egg producer)
	XY			XY
Zygotes	XX	XY	XY	YY
	♀	♂	♂? or intersex	♂

femaleness in the other (the female parent). Four kinds of combinations are theoretically possible. One will be a homozygous female (XX), another a homozygous male (YY). The other two will be heterozygotes. The combination XY will be male in sex differentiation, since, as we saw in cross 1, when a weak X is combined with a weak Y, the latter dominates. What will be the sex of a strong X combined with a strong Y has not been experimentally determined, but we should expect it to be either male or an intersex. It would appear accordingly that this cross between sex heterozygotes of two species differing in regard to sex dominance should produce chiefly male offspring, which was actually the result observed by Bellamy.

When do eggs and sperm acquire their respective plus and minus qualities, which cause them to attract each other? It was formerly thought that this occurred at the maturation of the germ cells, when they pass by a reduction division from the diploid or 2 n state in which each sort of chromosome is represented in duplicate, to the haploid or n state in which only one of each sort of chromosome is present. It was thought that the haploid state was itself a prerequisite to sex attraction on the part of the gamete. But this idea was shown to be erroneous when the Marchals were able in the case of mosses to induce the formation of gametes both by diploid or 2 n tissues and also by tetraploid or 4 n cells. Subsequently, both in flowering plants and in animals, gametes with two, three or more sets of chromosomes have been produced by various agencies, especially by subnormal or supernormal temperatures (cold or heat), the effect of which

has been to induce an uncompleted cell division, in which chromosome splitting occurs without the usual separation of the duplicated chromosomes into different cells. The result is the production of a cell with double the normal chromosome number which is capable of developing into a gamete. If such a diploid gamete unites with a normal haploid gamete, a triploid zygote results, in which each sort of chromosome is three times represented. And if two diploid gametes unite with each other, a tetraploid (4n) zygote results.

We thus are shown that development of the opposite and attracting qualities of gametes occurs whenever gametes are formed, irrespective of the number of chromosomes involved. Sex attraction is accordingly a somatic (cytoplasmic) differentiation involving the development of opposite (+ or −) characteristics in two classes of cells, the chromosome numbers of which, though normally haploid, *may be* diploid, triploid or irregularly haploid, with one or more chromosomes in duplicate or altogether wanting, conditions known as $n+1$, $n+2$, etc., or $n-1$, $n-2$, etc.

How is the somatic character of a gamete determined, *i.e.*, its sex reaction in distinction from the sex-gene which it transmits? Its somatic character is in agreement with and presumably determined by the sex of the parent which produces the gametes. A female parent produces eggs, a male parent produces sperm. But the sex of the parent individual itself was determined in the previous generation by the sex-gene content of gametes which united to form that parent. Only one seeming exception to this rule occurs to me. This is found in the case of hymenoptera, among the insects, in which the influence of the gametic nuclei is *always* female, never male. Yet male individuals are produced among the hymenoptera which furnish sperm for the fertilization of eggs. Such sperm, however, transmit only a female influence in the sex determination of offspring. They are only *somatically* male. How do they get that character? They develop from unfertilized eggs and so contain only nuclear material derived from their mothers, and this is female in its sex gene content. It must be, therefore, that the sex reaction of individuals which develop from unfertilized eggs is due to the nature of the egg cytoplasm, rather than its nuclear content. They are *somatic* males and produce sperm, but the nuclear content of those sperms has a female influence on the sex of offspring, since from all *fertilized* eggs females develop. This male somatic influence of the egg cytoplasm is accordingly contrary in nature to the nuclear influence of the egg, and it is strong enough to more than offset that influence when the egg remains unfertilized, so that a male individual results. But if the egg is fertilized and a second nuclear influence, that of a sperm, is added to the likewise female influence of the egg nucleus itself, then their combined female tendency overbalances that of the egg cytoplasm, and a female is produced.

We must then, in the case of the hymenoptera, recognize the *cytoplasm of the egg* as an agency in somatic sex determination equally important with the sex genes carried in chromosomes.

This is theoretically important, since it shows that cytoplasm as well as chromosomes may function in heredity, contrary to the commonly accepted idea that all inheritance is through the chromosomes of the cell nucleus. That non-chromosomal heredity is a reality is shown also by the work of Little and his associates on the inheritance of susceptibility to cancer in mice, in which maternal influence is much greater than paternal influence, being rated by the authors as more than six times more influential; also by the demonstration in mice and rabbits in my laboratory that the influence of the mother is greater than that of the father on the body size of offspring, a finding which is supported by a like result obtained by two other investigators

in species crosses of amphibia differing in body size.

When we oldsters took the general biology course thirty or more years ago, there were several groups of animals and plants known to reproduce sexually and yet among which no somatic sex differentiation was known to occur, either among the parents or among the gametes which they produced. This made it all the more reckless for me to hazard a guess that all gametes uniting in pairs were of opposite sex, but ignorance and youth are always courageous, and, as it has turned out, subsequent investigation has greatly reduced the field in which sexual differentiation of gametes is unknown. I beg to call your attention to three significant discoveries in this field.

About the time that I was speculating on paper about sex, I had as a pupil in a general zoology course a graduate student from the laboratory of Professor Roland Thaxter. He was working under Thaxter's direction on the sexual reproduction of the bread moulds and made the important discovery that they are sexually dimorphic. The bread moulds have long been a classic laboratory example in which to demonstrate the formation of zygospores, *i.e.*, sexually produced spores, by union of the tips of the thread-like hyphae of the fungus. But it was known to be tricky material. It was easy enough to grow the mould on stale bread kept moist and warm and to obtain quantities of the asexual spores, those which do not involve sexual reproduction; but to obtain zygospores was a gamble to the laboratory instructor. Sometimes they would form and sometimes they could not be induced to form in a laboratory culture. Blakeslee, Thaxter's pupil, better known now for his study of Jimson weeds, discovered why this is so. Mould plants grown from single spores are of two sorts, which Blakeslee designated + and – respectively, being uncertain which to call male and which female, or indeed whether their differentiation was of this nature. Zygospores form only when hyphae of a + plant come in contact with those of a – plant. Plus plants grown on agar plates side by side with plus plants, or minus plants grown side by side with minus ones, form no zygospores, but the moment a plus and a minus are grown side by side, abundant zygospores are formed, where their hyphae come in contact. Blakeslee showed that a similar sexual differentiation into plus and minus strains occurs in numerous other species and genera of fungi and that the plus strain is frequently more vigorous in growth and so possibly might with propriety be designated female. A plus plant will not give a sexual reaction (attempted formation of zygospores) if grown beside plus plants of any other species, but it will often give a sexual reaction to minus plants of other species or genera. This shows that a qualitatively similar differentiation as to sex occurs in many of the group, if not in all.

Another classic example among the lower plants of sexual reproduction without the occurrence of morphological differentiation in the uniting gametes was found among the algae, such as sea-lettuce, which reproduces by the formation of swarm spores, one-celled green flagellate individuals which frequently unite in pairs, though union is not obligatory to their continued life and growth. Hartmann has shown that union occurs only between pairs which are physiologically different. Like Blakeslee, in the case of the moulds, he recognizes among the algae plus and minus individuals. He also recognizes different degrees of plusness and minusness, which may be distinguished as strong pluses and weak pluses, strong minuses and weak minuses. Any plus will unite with any minus individual, whether weak or strong. Further, union may occur between a strong plus and a weak plus, or between a strong minus and a weak minus, if the difference between them is sufficiently great. This

leads him to formulate a principle of *relative sexuality.*

If Hartmann is right in this, we must accordingly extend our description of sex differentiation to include quantitative as well as qualitative differences in sex reaction. A sex union will occur only between gametes which are *different* in sex reaction, one female and one male, or one plus and one minus, or one with an *excess* of plusness or minusness as compared with the other.

Another of the troublesome problems of the general biology teacher, how to get paramecium to conjugate for class study, has recently been solved, with the discovery by Sonneborn, of Johns Hopkins University, that conjugation will occur only between individuals which are of different sex. As the two sexes are indistinguishable in appearance, Sonneborn calls them Sex I and Sex II, rather than plus and minus or female and male, as one might equally well do.

The sexual differentiation in this case is dependent on the character of the macronucleus, which must be qualitatively different in each member of a conjugating pair. In asexual reproduction the sex of a paramecium individual and that of all the offspring remains unchanged (since in this process the same macronucleus persists), but after conjugation (or endomixis) it is wholly a matter of chance whether the individual has the same or a different sex reaction as it previously had. This is because at such times the old macronucleus disintegrates and a new one is regenerated from a micronucleus, and this micronucleus may or may not be of the same sex as the old macronucleus.

In the conjugation of paramecium, as in the fertilization of a sea-urchin egg, we can recognize a two-fold sex differentiation. First there is a somatic differentiation of the conjugating individuals as of sex I or sex II, which attracts them to each other and occasions pairing. Before pairing any sex I individual will attract any sex II individual, but not afterward. Its differential charge has then ceased to exist. But there remains an attraction between gametic micronuclei developed in the conjugating pair. A "migratory" micronucleus leaves the body of each conjugant and passes over into the body of the other conjugant to unite with a "stationary" nucleus there, which is probably of different sex, since it attracts and fuses with the migratory nucleus, after which the attracting property ceases to exist.

Conclusion

We are now ready to formulate a tentative theory of sex. Sex is primarily a differentiation, electrical or otherwise, of the soma (cytoplasm) of gametes, which brings those of opposite character together and causes them to fuse. It is in agreement with and may be regarded as dependent upon the somatic character of the parent, being male when the parent is male, female when the parent is female.

The somatic character of a parent is determined as a feature of the Mendelian inheritance of sex-genes borne in the gametes which unite to produce that parent. In one system of sex determination found in flies and mammals maleness is dominant in heterozygous unions of sex genes, but in another system found in birds and moths femaleness is dominant in heterozygous unions.

An exception must be noted, in the case of hymenoptera, to the rule that sex genes borne in chromosomes (apart from hormone influence) exclusively determine the sex character of an individual. Male somatic differentiation of the unfertilized egg must in this case be ascribed to a male influence of the egg cytoplasm, which is strong enough to overbalance the female influence of a single set of chromosomes, but is inferior to the female influence of *two* sets of chromosomes exerted in the fertilized egg, even though one such set was brought to the egg in the sperm, the somatic character of which is male, though its sex-gene content is female.

THE PRESENT STATUS OF ESTHETIC MEASURE[1]

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From a certain point of view individual experience may be regarded as a succession of esthetic adventures. For example, in wandering upon an Alpine mountain side one may enjoy various flowers, occasionally noticing a single flower or cluster of flowers which is felt to be unusually lovely. And in all the occurrences of ordinary life there are many similar judgments of relative esthetic values. On considering this phase of our experience in more detail we become aware of the fact that what is appreciated is often some kind of unifying symmetry or other integrating type of order. Indeed it was long ago concluded that esthetic quality is correlated with unity-in-multiplicity. Yet this conclusion has to be carefully safeguarded in various ways; thus the mere repetition of an agreeable symmetry soon becomes wearisome if not actually unpleasant.

When I first became interested in esthetic questions nearly thirty-five years ago, I found that no thoroughgoing formalistic theory had ever been formulated. I felt that at the very least it should be possible to assess more adequately the rôle of the formal elements of order in determining the esthetic quality of an object. My own theory was finally embodied in a book "Aesthetic Measure," published in 1933. The general program called in the first place for the enumeration and quantitative estimate of the elements of order making for unity in the object. The arithmetic sum of these elements was designated as the order O. In the second place it was necessary to measure similarly the multiplicity or complexity C of the object. The ratio of O to C was called the esthetic measure M of the object, being associated with its degree of unity-in-multiplicity. It was hoped that in each of the specific classes of objects considered the esthetic measure M would roughly correspond to the esthetic value.

Of course the success of such a detailed program depended not only upon the selection of the really important elements of order in the object, but also upon a reasonable determination of its complexity. Psychologically speaking, the order O measured the favorable esthetic attitudes induced by the perception of the index of the number of items requiring consideration in the field of attention.

I realized fully that this was a most daring project, and also that there would necessarily be omissions and other imperfections in its execution even if it were fundamentally sound. Yet it seemed to me to be a step which was absolutely necessary if the subject of analytic esthetics were to be advanced. Perhaps as Dr. C. C. Pratt has said,[2] it was a "step which all formalistic theories have needed to take, but apparently have not been bold enough to attempt, ever since the days of Plato." I shall feel very well satisfied if my work serves to point the way to a more satisfactory formalistic theory, or even if it only leads to a better understanding of the formal factors in esthetic judgment.

[1] Address before the American Science Teachers' Association at Indianapolis, December 30, 1937.

[2] See his article "Structural *vs.* Expressive Form in Music," *Jour. Psychol.*, 1938.

Having thus set down an empirical theory which was susceptible of verification or disproof, I awaited with particular interest the experimental testing of its validity. Recently a very significant article by Drs. J. G. Beebe-Center and C. C. Pratt[3] has appeared which contains the results of experiments bearing on my theory and involving most of the types of objects which I had considered. My purpose here will be to indicate briefly the kind of analysis of esthetic measure which I had given in these cases, as well as the general conclusions of Beebe-Center and Pratt, and to add some comments and suggestions.

Before going further, one or two preliminary remarks concerning the concept of esthetic measure need to be made. In the first place, although the basic formula $M = O/C$ may be regarded as qualitatively valid always, its quantitative application must be limited to what I have called formal elements of order, in contradistinction to connotative elements of order. This refers to the well-known difference between form and meaning. For example, no formal theory such as that of esthetic measure can ever hope to deal with the elusive meanings which are present in a poem, although it might evaluate the musical quality. In the second place, it is precisely the elements of order whose presence we feel but have not explicitly analyzed that please us most by virtue of a certain occult quality. This does not mean, however, that if a profusion of formal elements occurs which we could analyze individually if time permitted, there would not be a similar effect. In the third place, the theory of esthetic measure in no way tends to a mechanical view of art. For instance, a definite scheme of measuring the formal beauty of a melody would not enable us to find sequences of notes which are remarkable in this respect. After all there would be the same difference as between discovering a diamond and assessing its value.

The first and simplest class of objects which I considered was that of polygonal forms, typified by tiles set in vertical position. The positive elements of order in O which I named were those of vertical symmetry, equilibrium, rotational symmetry and relation to a horizontal-vertical network. There were also certain negative elements of order which operated to diminish the esthetic effectiveness. The complexity C was taken to be measured by the number of lines containing all the sides of the polygon. For example, in the case of a square the complexity C would be four, and in the case of a Greek cross it would be eight. By way of verification of the theory I selected ninety polygons of varied form and arranged them according to the esthetic measures M theoretically assigned to them. As far as I could tell there was in general a decrease in esthetic quality along with the diminution in esthetic measure. This judgment was borne out by a crude experiment made by me while teaching one summer at Columbia University. Before informing the students in a large class about my theory I asked them all to arrange the polygons according to their own personal preferences. The arrangements showed general agreement with the theoretical predictions. It should be added that I instructed the students to disregard as far as they could irrelevant connotations such as, for instance, the religious connotation of the Greek cross. These connotations were of several types.

The first part of the study of Drs. Beebe-Center and Pratt dealt with polygonal form and was based on the judgment of six lay observers concerning forty-five

[3] "A Test of Birkhoff's Aesthetic Measure," *Jour. Gen. Psychol.*, 1937. Messrs. F. W. Swift, A. J. Schnittkind, H. W. Miller and Egbert Fischer collaborated in the experimental work carried out in this paper.

of the ninety polygons. The theoretic result according to the formula was treated as if due to a particular seventh observer B. It was found that there was a great deal of divergence in the individual judgments as to the relative esthetic merits of the forty-five polygonal forms, but on the whole the results were conformable to the theory, as will be shown by the following quotations. Of the six lay observers "two observers agree better with the rest of the observers than did the formula and four less well." The conclusion was that my "formula for polygons has a considerable degree of validity." It was found, curiously enough, that the results for groups of students of psychology or of art diverged far more within the group than did those obtained from lay observers.

A partial explanation of a lack of agreement between theory and experiment for some of the polygons may well lie in the following fact: There are certain polygons which so readily suggest other polygons that thereby a purely geometric association is established. For example, the six-pointed star will certainly suggest two related equilateral triangles. To offset this I had relied upon the specific use of actual tiles in embodying the various polygons, for I thought that in this way the consideration of further polygonal forms could be largely done away with. But I believe to-day that it is impossible to discount this particular type of suggestion, so that certain polygons must be ranked higher than the theory indicated. To take proper account of this esthetic effect I propose to introduce a further element of order P in the formula for polygonal form,

$$M = \frac{O}{C} = \frac{V + E + R + P - F}{C},$$

as follows:

In case the given polygon fully outlines the vertices of further convex polygons possessing exactly the same symmetries as the given polygon, P is R; otherwise P is O.

This asserts precisely that the presence of such outlined polygons doubles the effect of rotational symmetry. Only eight of the ninety polygons have their esthetic measures modified by this change, namely, Nos. 13, 23, 25, 29, 50, 51, 65 and 69 of my list. The rating of the six-pointed star No. 6 is unaffected since the outlined equilateral triangles do not enjoy the sixfold symmetry of the star.

It was just this kind of change which I foresaw that the theory of esthetic measure would need to undergo in its special applications. I wish to express thanks to Dr. Beebe-Center in this connection, since the above suggestion arose in my mind during stimulating talks with him about the experiments on polygonal form.

The second class of objects which I considered was that of simple vase forms. Here there was an obvious division of esthetic factors into three types: those related to utilitarian requirements, to regularity of outline and to geometrical relations of the contour seen in perspective. In my theory I devoted attention mainly to the third type of factor. As far as I could determine by constructing vase forms and by examining the photographs of certain ancient Chinese vases, the theory which I proposed was borne out to a reasonable extent. Nevertheless, I felt and still feel that the true elements of order are very difficult to determine. Fifteen plane figures representing the contours of vases were selected and rated by various observers in the experiments of Beebe-Center and Pratt. The general conclusion was of the same character as in the case of polygons, namely, that for the naïve observer the ". . . formula is as good a test of aesthetic value as is the average observer."

In this case, however, the judgments of a group of seven students and instructors

of fine arts which were consistent among themselves diverged widely from the predictions of the formula. Hence Beebe-Center and Pratt concluded that "the formula applied to vases is a good measure of aesthetic value as judged by laymen, but that it is a poor measure of aesthetic value as judged by sophisticated art students." It is conceivable of course that the group of seven students and instructors of fine arts had become so accustomed to a few accepted vase forms such as those embodied in Greek vases as to bring about a connotation operating against the appreciation of the wide variety of forms found in Chinese pottery.

To my way of thinking, the visual field of geometric form so far considered is much less likely to be crucial for the theory of esthetic measure than the auditory field connected with music. In his paper already referred to Dr. C. C. Pratt distinguishes between two kinds of form in music: structural form and expressive form. According to him expressive form for the individual results from the use of a "tonal design which resembles very closely the internal pattern of his own affective state." I should myself consider it as probable that such expressive form is due to an occult similarity to emotional utterances of the human voice or other expressive sounds. Of course expressive form would fall in the connotative realm which I excluded permanently from consideration at the outset as beyond the scope of any formalistic theory. In the auditory field I undertook to discuss the esthetic measure of single diatonic chords, of the sequences of two chords treated in harmony, of simple melody, and finally of the musical quality in poetry.

In the case of the chords I selected certain obvious elements of order, based upon a genetic study of the well-known nature of these chords. The general condition for a good diatonic chord consists in its degree of parallelism to an ordinary musical tone such as is found for instance in the human voice. The esthetic measure which I gave explained adequately the usual rules of harmony governing our preferences among the various diatonic chords.

In attempting the analysis of the esthetic quality of sequences of two diatonic chords which forms the basis of classical harmony, I began by taking the order O of a chordal sequence to be measured by the sums of the esthetic measures of the individual chords and of a certain transition value which was determined by explicit rules. Thus, if one passed from a dissonant chord to a consonant chord through a resolution, the transitional element of resolution was regarded as present. For the testing of these rules I was very fortunate in having at hand a classification of all possible sequences of such chords in fundamental position or in first inversion, which had been given by E. Prout, a widely known expositor of classical harmony. He had classified all these sequences into three groups, as good, possible or bad. There was as complete agreement as could possibly be desired between Prout's tables for 168 types of chordal sequences and the theory of esthetic measure.

When it came to the experimental study of such chordal sequences by Drs. Beebe-Center and Pratt, the inter-correlation on the basis of ten selected chordal sequences was found to be very low indeed, although the final conclusion was again of a similar character, namely, that my "formula for diatonic harmony is as good a test of aesthetic value in this field as is the judgment of an average observer." In their opinion and in my own, the low correlations have to do with the fact "that the observers frequently heard the chordal sequences as figures upon uncontrolled tonal background—images." For "it is almost impossible

for a person with any musical experience at all to hear a sequence of two chords completely detached from an imaged key-setting." From this point of view the ratings of Prout might then indicate the relative richness of various chordal sequences in power of entering into combination. But this would seem to me to be very strong evidence indeed that the factors which I isolated are substantially those which are esthetically effective.

In the case of melody the results were more favorable. Five unharmonized simple melodies were invented and their esthetic measures calculated. All five were of the same length and rhythm. None of them were established melodies, but the first was an inversion of the famous Chorale in the last movement of Beethoven's Ninth Symphony. Of the four others the relative ranking given by my theory was exactly the same as the average ranking of nineteen students of music. These same students, however, gave the inversion of the Beethoven theme third position instead of the first position which it should have had according to my theory and would doubtless have received if it had not been inverted.

A partial explanation of this divergence from the theory may be that these musical students recognized the inferiority of the inversion which violated the spirit if not the letter of a rule which I had formulated: "It must not be possible to increase the tonal order O by alteration within a short succession of notes (say not more than four), together with corresponding alterations in its repetitions, transpositions and inversions." In fact the original Beethoven chorals is essentially derived by such an inversion, and has a higher order O.

It is almost certain, however, that this explanation is not sufficient. Drs. Beebe-Center and Pratt conclude indeed that for melody the formula works "reasonably well," but that the average judgment appeared to be "more univocally determined by some factor as yet not properly taken account of in the formula of aesthetic measure of melodic value."

What then is the omitted factor? Before giving the probable answer to this question, it is of interest to observe that it was precisely in the process of constructing sequences with high formal rating but of inferior melodic character that I had previously determined certain factors which were overlooked in first attempts to set up a theory. In this work I was aided by an exceptionally intelligent and musically trained student who spent several months trying to "break" the theory, as I had instructed him to. At the end we both came to the realization that it was getting very difficult indeed to set up an unmelodic sequence of notes with high rating and quite impossible to find a familiar melody with a low rating.

Now the inversion of the Beethoven chorale referred to above proves on further inspection to have a serious formal flaw, not forbidden by the seven "further conditions of satisfactory form" which I had enumerated but which should be excluded by the first condition referring to "regularity of pattern." Let me state this omitted requirement:

The tonic note, in its first appearance (not imbedded *within* a subdominant or submediant sequence) must either be the first or last note of the melody, or part of a tonic sequence at the commencement of the melody, or an accented note, or an unaccented note within a tonic sequence. Otherwise the tonic center is not felt to be properly announced. In glancing over about one hundred well-known simple diatonic melodies in four-part time, I have not discovered any exceptions to this requirement of satisfactory form.

In the original Beethoven chorale which starts with the four measures[4]

[4] In this notation 1 designates the tonic, 2 the supertonic, etc.

| 3345 | 5432 | 1123 | 3222 |,

the tonic center is appropriately introduced at the first accented note of the third measure. But in the inversion under consideration,

| 3321 | 1234 | 5543 | 3422 |,

the tonic makes its appearance at the fourth unaccented note of the first measure and yet is not part of a tonic start or imbedded in a tonic, subdominant or submediant sequence. Hence the tonic center is improberly announced, and even the untutored ear feels that something is wrong, without knowing what it is. If the inversion is modified in the first measure to any of the manifold alternative forms complying with the rule it will be found that the particular kind of disagreeableness in question disappears. Unfortunately, the melodic sequence loses in other elements of order thereby; in particular the third measure is no longer an exact transposition of the first.

Thus this experimental melody serves to bring to light a supplement to my condition for regularity of pattern—the omitted factor.

On inquiry of Professor W. H. Piston he kindly informs me that, so far as he knows, no similar musical requirement has been stated anywhere, although he can think of no obvious exceptions to it in relevant musical works. Unless I am badly mistaken there are brought to light in my theory of esthetic measure many similar instances of 'unwritten' formal laws in esthetic fields. And it is a considerable part of my claim that the totality of such laws, explicit and implicit, determines the esthetic judgment of form.

One further remark may be made here. As originally brought to me by Mr. Fischer the proposed melodic sequence was an exact inversion of the Beethoven chorale:

| 3321 | 1234 | 5543 | 3444 |.

But I pointed out that this would not do because it violated the condition for regularity of pattern in its lack of cadences. For this reason it was modified by Mr. Fischer as indicated above, to the definite improvement of its melodic quality. I did not go further into the matter at that time, since the main object of the experiments was to test the theory of esthetic measure exactly as I had formulated it.

It was in the application to musical quality in poetry, where first experiments appeared to indicate a definite failure of the theory, that the clearest confirmation of its general validity was found. In my own study I had fixed upon the obvious elements of alliteration and assonance, of musical vowels and of rhyme, as giving the principal elements of order. On the other hand, I had measured the complexity by the number of simple sounds. With this basis I analyzed a number of poetic passages and found relative esthetic measures which agreed with my own judgment and that of several persons whom I consulted. In the preliminary experiments with poetry made by Drs. Beebe-Center and Pratt there was found at first an almost complete lack of correlation between the judgments of the various observers. It was still true, however, that my formula agreed "better with the group as a whole than any member of the group," even if the agreement was low. Here the possibility was indicated that there was a great interference of poetic meaning with the impartial judgment of the intrinsic musical quality of the lines.

On this account seven nonsense lines were constructed having esthetic measures which varied from 1.16 down to .40 according to the formula. These lines were read to five persons individually. The first line with highest rating according to the theory was:

Salanta moanralume oarimely loase;

and the one with lowest rating was

Bered ak filner dinstem jeebenot.

The results obtained showed that the "formula represents empirical aesthetic value as well as it possibly could with the experimental technique." In fact, the highest average correlation of any observer with the others was .75, which was just the same as that of the formula. This conclusion was in agreement with results which had been previously reported by Dr. R. C. Davis,[5] although Davis's results concerning polygonal forms were apparently adverse to the theory of esthetic measure.

Thus it appears from the various experimental findings of Beebe-Center and Pratt that the specific formulas which I had constructed more or less empirically "are valid as first approximations to quantitative rankings of aesthetic value." Naturally a great deal of further work will have to be made before the exact extent of their validity is known. More elaborate experiments are now being made under the direction of Dr. Beebe-Center, in which it is hoped that the method of factor analysis will throw light upon further experimental data.

In conclusion I would like to refer to an interesting suggestion of Dr. Beebe-Center's that there may be two or more kinds of observers: as, for instance, the lay observer of objective type who unconsciously takes account of utilitarian qualities possessed by the object; and the much rarer, esthetically minded observer, who is influenced by accidental and variable connotations. Dr. Beebe-Center thinks it is possible that "aesthetic measure" may be more representative of the objectively minded observer than of one of the second type, to whom indeed no formalistic theory would be likely to apply with any degree of success. I must confess personally to considerable distrust of the latter, *quā* observer.

[5] "An Evaluation and Test of Birkhoff's Aesthetic Measure Formula," *Jour. Gen. Psych.*, 1936.

FUNDAMENTAL RESEARCH AND ITS HUMAN VALUE[1]

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THE keynote of this congress is the application of science to human needs. To gauge the power of science to meet present and future needs, let us examine the methods by which science has been used to solve problems of the past.

MODERN LIFE DEPENDENT ON SCIENCE

Modern life is absolutely dependent on applications of science. Consider, for example, the conditions that would arise in any large city if we had to return to the systems that were in use a century ago for sanitation, for water supply and for the distribution and preservation of food! The lives that have been saved through the work of Pasteur, and of those who have applied his discoveries, must surely now be counted by the tens or even hundreds of millions. Think of the reduction of human suffering by anesthetics, by surgery, by the elimination of diseases such as plague, yellow fever, smallpox, typhoid, malaria and tuberculosis. The steamship, railroad, automobile and now the airplane provide transportation indispensable to us. Electric power and light add to the comfort and efficiency of nearly every one in many countries. Consider also the telegraph, telephone and radio; cement, new metals and alloys, plastics, oil as fuel, etc.

The modern increased standard of living has depended not only upon such things as these, but upon labor-saving devices and methods which have resulted from the application of science. Only by producing vastly more than our forefathers has it been possible for us to consume more.

Another thing of perhaps greater importance that science has done has been to give mankind a new outlook on life. The theory of evolution has done much to set us mentally free. Enough of the scientific attitude has permeated the masses of mankind to eliminate many superstitions that caused much suffering through fears that have now been abolished.

All these changes that have resulted from the application of science have led in recent years to perhaps the greatest revolution in the history of mankind. The rapidity of these changes seems to be continually accelerating. Judging from the volume of scientific publications in the last thirty years there seems to be an increase of about 6 per cent. per year in scientific activity, or a doubling every eleven years.

Of course, such a rapid change has not taken place without bringing many new and serious problems. Much of our present economic maladjustment is due to a failure of our social organization to keep pace with the changes brought about by scientific progress.

EARLY PROGRESS MADE BY INVENTORS AND ENGINEERS

Until the beginning of the present century, applications of science had almost always been made by inventors and engineers who had utilized the stock of scientific knowledge available to them and who did not themselves contribute to

[1] Delivered by the author as a paper before the seventeenth Congress of Applied Chemistry at Paris, September 30, 1937, and printed in the December number of *Chimie et Industrie* with the title "La recherche scientifique pure et son importance au point de vue humain."

fundamental science. Pure science was mainly the outgrowth of work carried on in universities by those who were not primarily interested in the applications. Newton, the great French mathematicians and physicists Laplace, Ampere, Poisson, the chemical pioneer Lavoisier, the great English scientists Faraday and Maxwell, are names selected at random of those who laid the foundations for present science. Engineers and inventors, men like Edison, Elihu Thomson, Marconi and Bessemer, have applied science to meet human needs, but not many of them made great contributions to science itself. Pasteur is perhaps the most important exception. He was one of the greatest of scientists, and at the same time he made applications of science having the utmost direct value to mankind.

Establishment of Industrial Research Laboratories

Beginning about 1900, many industries established research laboratories whose object was primarily to apply existing scientific knowledge to the solution of industrial problems. Only a small fraction of this total knowledge had received industrial application, and it must have seemed to the leaders of industry as though the supply of available unused knowledge was almost inexhaustible. The industries felt no need or obligation either to contribute to or to extend the fundamental knowledge; it was only necessary to develop the applications to their particular needs. The age, after all, was one of unscrupulous exploitation of natural resources.

The success of industrial laboratories has been so great that in 1934 there were said to be 1,200 industrial research laboratories, employing about 30,000 people, in the United States alone. Undoubtedly the contributions of the industrial laboratories have now become more important than those of individual inventors and engineers.

In the vast majority of cases the work done in these industrial laboratories is directed toward specific ends; that is, it is aimed to solve problems which are known to exist within the industry.

In the past, however, a great many problems have been solved and have led to great benefits to mankind where a few years previously it was not even suspected that there was a problem to be solved. For example, there was no recognized need for the telephone or phonograph, nor for radio broadcasting until these improvements were already developed. A good example, which has forced itself strikingly on my memory, is that students of Union College, Schenectady, were broadcasting phonograph records every Thursday evening for the amusement of their amateur listeners several years before any of the commercial broadcasting stations were inaugurated, and yet the officials of the General Electric Company, many of whom knew of this, did not realize that such broadcasts were of any value. In other words, many great and important inventions or discoveries need to be thrust upon us before we can see their value. To expect that a director of an industrial laboratory will recognize the need for all the scientific developments which may be of importance to his industry is thus to expect him to be a superman.

Establishment of the General Electric Research Laboratory

In the year 1900, Mr. E. W. Rice, Jr., established within the General Electric Company at Schenectady an organized industrial research laboratory for the purpose of carrying on fundamental industrial research. It was planned that this laboratory should be devoted exclusively to original research or to the study of natural phenomena in search for new facts and principles. Mr. Rice was thus not content to draw from the storehouse of scientific knowledge built up in uni-

versities but wished to have a laboratory in which scientific progress could be accelerated and the frontiers of knowledge extended in directions which would be likely to prove useful to the industry. Such research can not usually be directed toward definite goals, for it involves unknown factors. Success in such research, if attained, is often reached by wholly unexpected methods, and the problem which is finally solved is not the problem which is foreseen.

As this laboratory developed it was soon recognized that it was not practicable nor desirable that such a laboratory should be engaged wholly in fundamental scientific research. It was found that at least 75 per cent. of the laboratory must be devoted to the development of the practical applications. It is stimulating to the men engaged in fundamental science to be in contact with those primarily interested in the practical applications. It is also important that the engineers in the organization should be in close contact with those having the broader scientific outlook.

Let me give an example of the useful interaction of the two groups of men. Let us suppose that through the discovery of a new scientific principle or fact the possibility of some new application is opened up. The men trained in pure science are usually not the men to make most rapid progress in the applications; on the other hand, it is not possible to turn the work over immediately to a separate engineering research laboratory. The growing idea, like a child, must not be weaned from its mother too soon. Before the continued development of the idea can be assured in the hands of an engineering staff, it is necessary for a relatively large amount of engineering research to be carried out by the originators of the idea or those closely associated with them, for only these have the necessary familiarity with the subject and the deep personal interest required for success.

If, however, some provision is not made for a separate engineering research department there is great danger that the engineering research may grow to such proportions as to undermine the spirit of fundamental research which should dominate the research laboratory if its proper functions are to survive. In the General Electric Company we have been fortunate in having several such engineering departments which are capable of taking over any problem from the research laboratory as soon as its ultimate success seems assured.

Personal Experiences in Research Work

I will give you some examples from my own personal experience to illustrate how fundamental scientific work undertaken without definite applications in view can result in discoveries that are of direct benefit to mankind. I want to show you how, in these cases at least, the practical result could hardly have been reached in a laboratory in which the workers were assigned definite work directed towards a goal. There was no one who had the vision to see the goal until we had nearly reached it.

When I started to work in our research laboratory, Dr. Whitney, who was then director, instead of assigning me to a definite problem, suggested that I spend several days in the various rooms of the laboratory becoming familiar with the work that was being done by the different men. He asked me to let him know what I found of most interest as a problem to work on.

I was particularly interested in the work that was going on in the laboratory with tungsten-filament lamps of the high-vacuum type. Much work had shown that the higher the vacuum the better was the lamp—that is, the less rapidly the bulb blackened. What interested me most, however, were the wonderful possibilities opened up to the scientist by having a material like tungsten, which could be heated to temperatures over 3400 C. If residual gases produced

harmful effects in a lamp, it seemed to me that it was a fascinating field for investigation to study the effects produced by each different gas separately introduced into the bulb. This work was not undertaken with a definite idea that it would lead to an improvement in the lamp; it was merely done to satisfy my own curiosity as to the interactions between gases at low pressures with filaments at high temperatures, a field of study which, I believe, never had been undertaken before. From Dr. Whitney's point of view it was a useful line of research for the General Electric Company because it would give us increased knowledge of the type of phenomena that are presumably occurring in lamps. The whole consensus of opinion in the laboratory, however, was that the direction that should be followed in seeking to improve the lamp was to obtain a far better vacuum than had previously been possible.

I worked for about three years studying these chemical reactions at low pressures with filaments at high temperatures, and published several scientific papers giving the results of this work. I was particularly interested in the results obtained by introducing hydrogen into the lamp, for this gas caused a very great heat loss from the filament. I was able to show that this was caused by the dissociation of hydrogen molecules into atoms. In order to make sure of the correctness of this explanation, I was led to experiment with nitrogen and with mercury vapor over a wide range of temperatures and pressures up to and including atmospheric pressure. At this time no one in the laboratory had any idea that any benefits could result from such gases.

Gas-filled Lamps

To be able to measure quantitatively the degree of dissociation, I needed to know how much heat was carried away from the filament by conduction and convection of heat by the gas. To get at the scientific facts underlying this loss of heat, I made experiments with filaments of various sizes and found the rather surprising result that a tenfold increase in the diameter of the filament in the case of a gas at atmospheric pressure caused only a relatively slight increase in the heat that was carried away by the gas.

In working with nitrogen, I found that the nitrogen had a peculiar tendency to disappear, and was able to prove that this was due to a chemical reaction by which each tungsten atom which evaporated from the filament combined with nitrogen to form a compound WN_2. In order to study this reaction I needed to determine the rate of loss of weight of tungsten filaments at different temperatures. I found that this loss of weight was due to evaporation, and not, as had been previously considered, to an effect of electric discharges. When working with nitrogen at atmospheric pressure, the rate of evaporation was decreased about a hundredfold because of the return of the tungsten atoms to the filament after they collided with nitrogen molecules in the gas.

I had noticed that with nitrogen at atmospheric pressure it was possible to maintain a filament at a temperature close to the melting point for a far longer time than if the filament were in a vacuum. I knew, however, that this increased life was more than compensated for by the increased loss of heat caused by the nitrogen. However, the laws of heat conduction which I had discovered indicated that if we used filaments of very large diameter carrying about 20 amp of current, the effect of the heat loss would not be so serious. This suggested the possibility of constructing lamps of high efficiency with nitrogen at atmospheric pressure by using filaments of very large diameter. This led to the construction of what was known as the half-watt lamp. Within a few months, improvements were made by substituting a coil, so that the effect of a large diameter filament could be obtained by a filament taking rela-

tively small currents and by the substitution of argon for nitrogen.

I want to call your attention particularly to the fact that there were many separate lines of pure scientific work which contributed to this successful result. There was nothing from the prior knowledge that suggested that any benefit would result from the addition of gas to the lamp; in fact, there was no lamp made in 1911 which would have been given an improved life or efficiency by the introduction of nitrogen. It required the construction of an entirely new type of lamp based on new scientific principles before this benefit could be obtained.

As soon as we received positive indications that an improved efficiency of the lamp would be possible through the use of argon and nitrogen, a large group of men in the laboratory worked on the development of this type of lamp. It took about six months of intensive work on the part of about twenty-five men before their results could be turned over to the development laboratories of the incandescent lamp factories, and it was about a year before these lamps were ready for manufacture.

Study of Thermionic Emission

As soon as this group started working on this problem, I began to devote my attention almost wholly to a study of electric discharges in lamps containing gases at very low pressures. With the high degree of vacuum which was used in ordinary lamps at that time it was found that the electric currents that could flow across the space between one end of the filament and the other, even with voltages of over 100 volts, were only a very few milliamperes. This fact seemed very peculiar to me, for the work of Richardson and others had indicated that at temperatures as high as those used in the tungsten-filament lamp, currents of many amperes should flow across the space. In other words, according to the then-accepted theory of the electron emission from hot filaments, a serious difficulty should have been encountered in the construction of tungsten-filament lamps. The fact that we did not meet any such difficulty therefore seemed to me a peculiar fact that should be investigated.

Now, in an industrial laboratory which is devoted to the solution of specific problems, it would not be reasonable to undertake an investigation to find out why no difficulty was found in the construction of lamps; there was no problem to be solved and therefore no need for any work in this field. I was only interested, however, in a thorough understanding of all the phenomena taking place in lamps, so I began to make a detailed study of the laws that govern the flow of current between tungsten filament in high vacuum. A few days of work led to the discovery of a new effect known as the space-charge effect. The electrons that escape from the hot filament require a definite time to cross the space to the positively charged end of the filament, and while these electrons are crossing the space they are repelling those that are leaving the filament behind them, therefore there is a definite limit to the current that can flow with a given impressed voltage. If a very small amount of gas is present, positive ions are formed which neutralize the effect of the negative charges on the electrons and thus permit large currents to flow. This explained the arcing of lamps that occurred with the presence of gas at pressures as low as 1/1000 of a millimeter.

I was able to work out mathematically the laws that govern the flow of current in high vacuum when this current is limited by the effect of space charge. In ordinary incandescent lamps this effect would limit the current to a few milliamperes, but by special construction using electrodes very close together and using much higher voltages, as I was able to see from this theory, it should be possible to obtain large currents in very high vacuum and at very high voltages.

Dr. Coolidge was then working on the use of tungsten electrodes for x-ray tubes

of the usual type which required the presence of gas. The new theory of electron space charge indicated that by using a vacuum several hundred times better and a hot tungsten filament as cathode, it should be possible to construct an x-ray tube of an entirely new type. These tubes were constructed and developed by Dr. Coolidge utilizing the new principles of high-vacuum discharge.

At that time, 1912, the deForest Audion had been used in detecting and amplifying radio signals. It was essential, however, in the operation of these tubes to use a certain amount of gas of about 0.005 mm pressure. In fact, the tubes were purposely made with a poor vacuum, for they failed to operate satisfactorily if the vacuum was too high. These Audions were always operated at about 20 to 25 volts on the plate and at a current of about 0.1 milliamp. They failed completely to work at higher voltages because of the wasting away of the filament and because of the development of "blue glow."

An understanding of the space-charge phenomena, however, gave an explanation of the fact that the Audion required the presence of gas for satisfactory operation. If the gas was pumped out of such a tube, the currents were too small to be effective, and the grid construction that had been used was no longer satisfactory. By using a vacuum hundreds or thousands of times better, we were soon able to operate at voltages of 10,000 volts and currents of 100 milliamp. This development, which took the Audion out of the field of a detecting tube for radio and made is application possible to the field of radio telephony and broadcasting, was thus the outgrowth of experiments undertaken solely to satisfy scientific curiosity. There was no one in the General Electric Company who was conscious of the need of a high-powered electron amplifier. However, once we were led to the construction of such a device we could immediately think of an enormous number of applications for it. This is another illustration of the fact that fundamental scientific research in an industrial laboratory is likely to lead to new and unforeseen applications.

The work on the heat losses from tungsten filaments in hydrogen had led to the discovery of atomic hydrogen and had given measures of the great amount of heat absorbed by the dissociation of the hydrogen. A few years later Professor R. W. Wood showed that when an electric discharge is passed through hydrogen at low pressures atomic hydrogen is formed, and that this can recombine on the surface of metal wires and cause them to be heated. My interest in this field and the work that I had previously done led me to see then that still greater results could be obtained by using hydrogen at atmospheric pressure with a high-current arc. I was thus led to develop the atomic hydrogen welding process for metals, which makes possible the welding of chromium steels and facilitates obtaining vacuum-tight welds. This proved to be an important factor in the fabrication of the sealed-in electric refrigerator unit, which helped to adapt electric refrigeration to domestic use.

About 1916 to satisfy a scientific curiosity and with no applications in view, I made some studies of the condensation of tungsten vapor on glass surfaces, and later continued this work with mercury and cadmium, and was able to show that certain ideas that had been proposed by others in regard to the nature of this condensation were incorrect. It had been maintained that at certain temperatures atoms of mercury and of cadmium could be reflected from a surface; that is, the molecules upon striking the surface would bounce off again. I showed that the phenomena could be better explained by assuming that the molecules or atoms on striking the surface always condensed, and that then, after a certain time interval depending on the temperature, they would evaporate off. This theory played an important part in the development of

theories of absorption of gases on surfaces. Shortly after this, Gaede described the construction of a mercury-vapor pump called the diffusion pump, which gave an extraordinarily high vacuum but was a pump of essentially low speed, the maximum speed being only about 80 cc per sec. This low speed resulted from the fact that the diffusion occurred through a narrow slit. Gaede pointed out that the slit could not be made wider without causing a lowering in the speed of the pump. From the work that I had done on the condensation of mercury vapor on glass, knowing that the molecules were not reflected, I was in a position to realize immediately on reading Gaede's article that the serious limitation in the speed due to the narrowness of the slit employed could be avoided by depending on condensation of the mercury on a cooled glass surface, involving a simple but novel design of the pump. This resulted in the construction of the condensation pump, which immediately increased the speed of the mercury-vapor pump from 80 to about 4,000 cc per second. Again you will notice that it was only investigations conducted for their pure scientific interest that led to the improvement in the pumps that I have described.

Monolayers and Multilayers

The work with tungsten filaments and gases done prior to 1915 had led me to recognize the importance of single layers of atoms on the surface of tungsten filaments in determining the properties of these filaments. For example, a single layer of oxygen atoms would decrease the electron emission of the tungsten by a factor of 10,000, whereas a single layer of thorium atoms would increase the emission 100,000-fold. I recognized that this powerful action of monolayers of atoms resulted from the very short ranges of the forces that act between atoms and molecules. This view led me to believe that on the surfaces of liquids single layers of molecules should also be important in determining such properties as surface tension. I was led to make investigations of films of oil on water, and showed that such substances as olive oil spread out on the surface of water to form a layer which is just one molecule thick. By measuring the area to which a given amount of oil would spread one can thus measure the dimensions of the molecules. These results were published about 1918. I did very little further work in this field until about 1931. In the meantime, however, others had undertaken work along these lines, and some of the interpretations of the experiments that had been made were, I believed, erroneous. I was therefore led to write a paper on the structure of monolayers of fatty acids on water in 1931. This aroused my interest anew in this field. Later my assistant, Dr. Katherine B. Blodgett, who was making studies of these films on water, found that under carefully controlled conditions, using salts of barium or calcium in the water, films of stearic acid could be built up on a glass or metal plate in successive layers by merely raising and lowering the plate through a water surface. We have been studying these multilayers for the last few years. They have led to results of considerable scientific interest. We find that by depositing several hundred layers, counting the layers as we deposit them, we can get optical effects such as interference colors which enable us to measure with great precision the dimensions of the molecules of many substances. It also serves as a means of measuring the absolute values of the wave-lengths of x-rays. Until recently, however, we have not seen how these results could be directly applied to human problems or to human needs.

Last December Dr. Dorothy Wrinch visited our laboratories and asked if we could apply the technique which we had developed in the study of multilayers of fatty substances to the study of proteins. After a few days of work, we found that we were able to build up multilayers of

any protein on metal plates and in that way we were able to study many new properties of these important substances. We found that if we take a strip of chromium-plated brass and build up on it 49 layers of barium stearate and examine it with the naked eye by monochromatic light from a sodium-vapor lamp there is a sharp minimum in the intensity of the reflected light at a definite angle of instance. If now the plate is immersed for a few seconds in water containing thorium nitrate and is then washed, the plate then becomes capable of taking up from a solution into which it is dipped certain substances such as proteins and many other bodies of biological interest. The plate can then be washed with water and dried and again examined with monochromatic light. Any increase of thickness due to the substance taken up from the solution, even if only of 2×10^{-8} cm, is readily visible to the naked eye.

We have thus evolved a method of rendering visible single layers of atoms or molecules. It is a quantitative method which enables us to make measurements of the diameters or sizes of molecules of many different substances. For example, if we dip the prepared plate into a solution of egg albumen we get an increase of thickness of 50×10^{-8} cm, whereas if we dip it into a dilute solution of another protein, the virus of the tobacco mosaic disease, which is known to be a protein having a very large molecular weight (17,000,000) there is an increase of 300×10^{-8} cm. Each different protein that we have tried gives its own characteristic thickness by a measurement which takes only a few minutes.

Furthermore, we find that the proteins thus taken up by the plate retain their biological activity. For example, the plate will take up a layer of diphtheria toxin, and then, although it will not take up any more toxin, it will take up the diphtheria antitoxin. It looks therefore as though this method of rendering these thin films visible should have great value as a biological tool; very likely it will find a place in the diagnosis of disease. It has the advantage that it makes possible the detection of extremely minute amounts of substances from very dilute solutions. By a modification of this technique, for example, we find that we can detect inorganic salts in water at concentrations as low as 10^{-9} molar, which is about 1 part in 10 billion parts of water. Thus these experiments with multilayers seem to open up several promising lines of research which may well have applications to human needs.

The examples that I have given you show that many radically new things for the home as well as elsewhere come from fundamental research and are not foreseen while the research is in progress. Such foreknowledge is impossible in many cases, for the research leads to new facts and a better understanding of fundamentals which makes the application possible.

I do not wish to leave the impression that all industrial research can profitably be of the fundamental type that I have outlined. It is usually the large industry which can best afford to undertake work of this kind. Wherever specific problems are definitely known to exist, it is of course logical to organize research work for the solution of these problems. If, however, in a large laboratory 10 or 20 per cent. of the men are given an almost free hand to follow up new and promising lines of pure scientific research, and, particularly, are encouraged to make a thorough scientific study of the nature of the phenomena involved in industrial processes, the industry may benefit from radically new developments which could not occur by any planning on the part of the directors of the laboratory.

RECENT ADVANCES IN THE THEORY OF FERROMAGNETISM

By Dr. RICHARD M. BOZORTH

RESEARCH PHYSICIST, BELL TELEPHONE LABORATORIES, NEW YORK, N. Y.

In the last five or ten years the theory of ferromagnetism has finally shown signs of maturity. For the first time a story can be told concerning the ultimate magnetic particle, the essential nature of the atom of a ferromagnetic substance, the kind of forces which determine the properties of magnetic crystals, the effect of strain on magnetic materials, and the manner in which these various phenomena combine to determine the properties of commercial materials. It is true that the story is largely qualitative, and that there are still many points that are uncertain or missing entirely, but nevertheless it is possible at least to discuss them.

The fundamental magnetic particle is the spinning electron. Although one might think that the orbital motions of the electrons in the atom would also contribute to ferromagnetism, since these give rise to magnetic moments, it has now been established that when the magnetization changes, it is only the direction or sense of the spin of certain of the electrons in the atom which changes—the orbital motions remain as before.

The electrons that are responsible for the magnetic properties of iron, cobalt, nickel and their alloys lie in a definite "shell" in the atom. As shown in Fig. 1, there are four shells or regions, more or less well defined, into which all the electrons circulating about the nuclei of these atoms may be divided when the atom is separated from its neighboring atoms, as it is, for example, in a gas. Some of these shells are subdivided as shown. When the atoms come closer together as they do in a solid, the fourth or outmost shell becomes disrupted, and the two electrons which comprised it wander from atom to atom and are the "free" electrons responsible for electrical conduction. The electrons in the outer part of the third shell are those responsible for the distinctive kind of magnetism found in iron, cobalt and nickel. Some of these electrons spin in one direction and some in the opposite, as indicated, so that their magnetic moments partially neutralize each other, and it is the excess of those spinning in one direction over those spinning in the other that causes each atom as a whole to behave as a small permanent magnet.

The well-established kinetic theory of matter tells us that if each atom were to act independently of its neighbors, the atoms would be vibrating and rotating with such strength that they could not be aligned even with the strongest field that can be produced in the laboratory. To explain the kind of magnetic properties found in iron, therefore, it is necessary that there be some force present which will make the magnetic moment of a group of neighboring atoms lie parallel to each other—the small atomic "permanent magnets" of each group must point in the same direction so as to provide a magnetic moment great enough to permit a realignment when subjected to external fields. Recently it has been shown by independent means that there is such a force in just those elements which are ferromagnetic, and it is from this force that the difference between magnetic and non-magnetic materials arises. The force is electrostatic in nature and is called

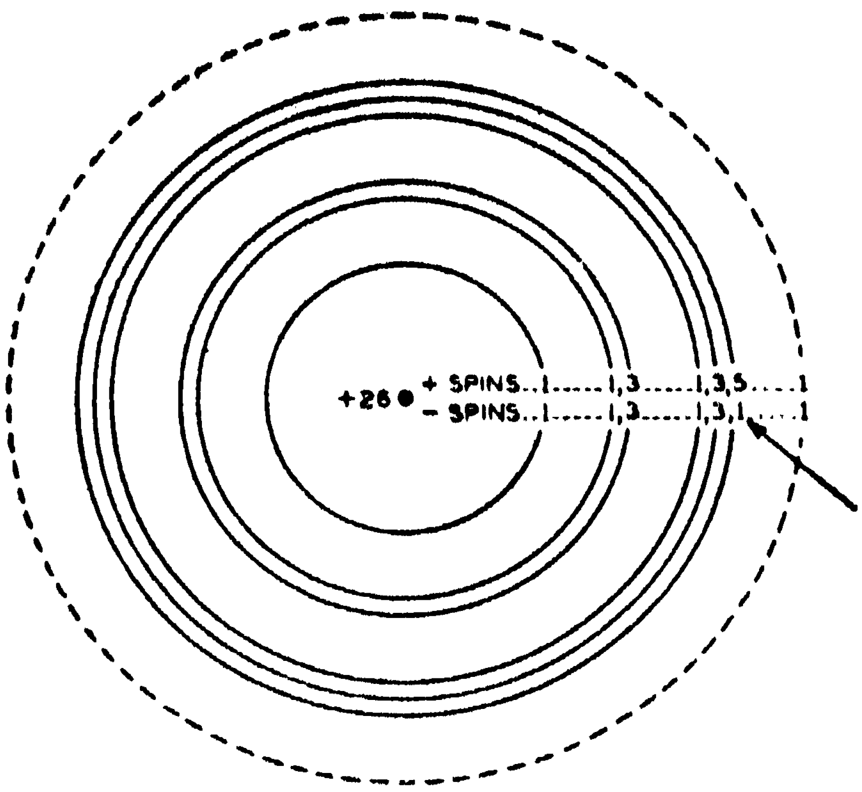


FIG. 1. ELECTRON SHELLS IN AN ATOM OF IRON. THE ARROW INDICATES THE SUB-SHELL THAT IS RESPONSIBLE FOR THE MAGNETIC PROPERTIES.

"interaction" by the atomic-structure experts, the wave mechanicians, who have shown its existence and calculated its order of magnitude. This force maintains small groups of atomic magnets parallel against the forces of thermal agitation, unless the material is heated so hot that the disordering action of the agitation becomes strong enough to overpower the forces of "interaction." When this occurs the material loses its ferromagnetism; in iron this happens at 770° C.

For some reason not at all understood at present, at ordinary temperatures the electrostatic forces of "interaction" maintain the elementary magnets parallel only over a limited volume of the specimen. This volume is of the order of 10^{-9} cubic centimeters, and contains a million billion atoms, but would be too small to be seen by the naked eye if it were isolated. Such volumes are said to be saturated because the atomic magnets are all pointing the same direction, and have been given the name *domains*. Thus a magnetic material at room temperature, before it has been magnetized by subjecting it to the influence of a magnetic field, is divided into a great many domains, each of which is magnetized to saturation in some direction generally different in neighboring domains. The net or vector sum of the magnetizations is thus zero, and externally the material appears to be unmagnetized but in reality the magnetization at any one point is very intense. When a magnetic field is applied by bringing a permanent magnet or a coil of wire carrying a current near the metal, the magnetization of the material as a whole is increased to a definite value. The mechanism by which this takes place is simply the change in direction of the magnetization of the domains. If we represent the magnetization at any point by a vector, the effect of the externally applied field is only to rotate the vector—to change its direction but not its magnitude.

Recently much has been learned about the magnetic properties of materials by a study of single crystals. Ordinary metals are composed of a great many crystals often too small to be seen easily by the naked eye. But in the last few years methods have been found to make large crystals of almost all the common metals, crystals as large as the more familiar ones of rock candy and even of quartz. Experiments on such crystals of iron show that they are much more easily magnetized in some directions than in others, and these directions are called "easy" and "hard" directions of magnetization.

This dependence of ease of magnetization on direction is illustrated in Fig. 2 for iron and nickel in relation to the positions of the atoms in the crystals. The circles represent the atoms which take up positions on an imaginary framework or lattice. Because of the smallness of atomic dimensions only a small fraction of the atoms in a crystal of ordinary size are shown, but the same pattern, the unit of which is outlined by solid lines, extends throughout the whole of the single crystal. The arrows indicate the directions of easy magnetization, which are different for the two materials as may be noticed.

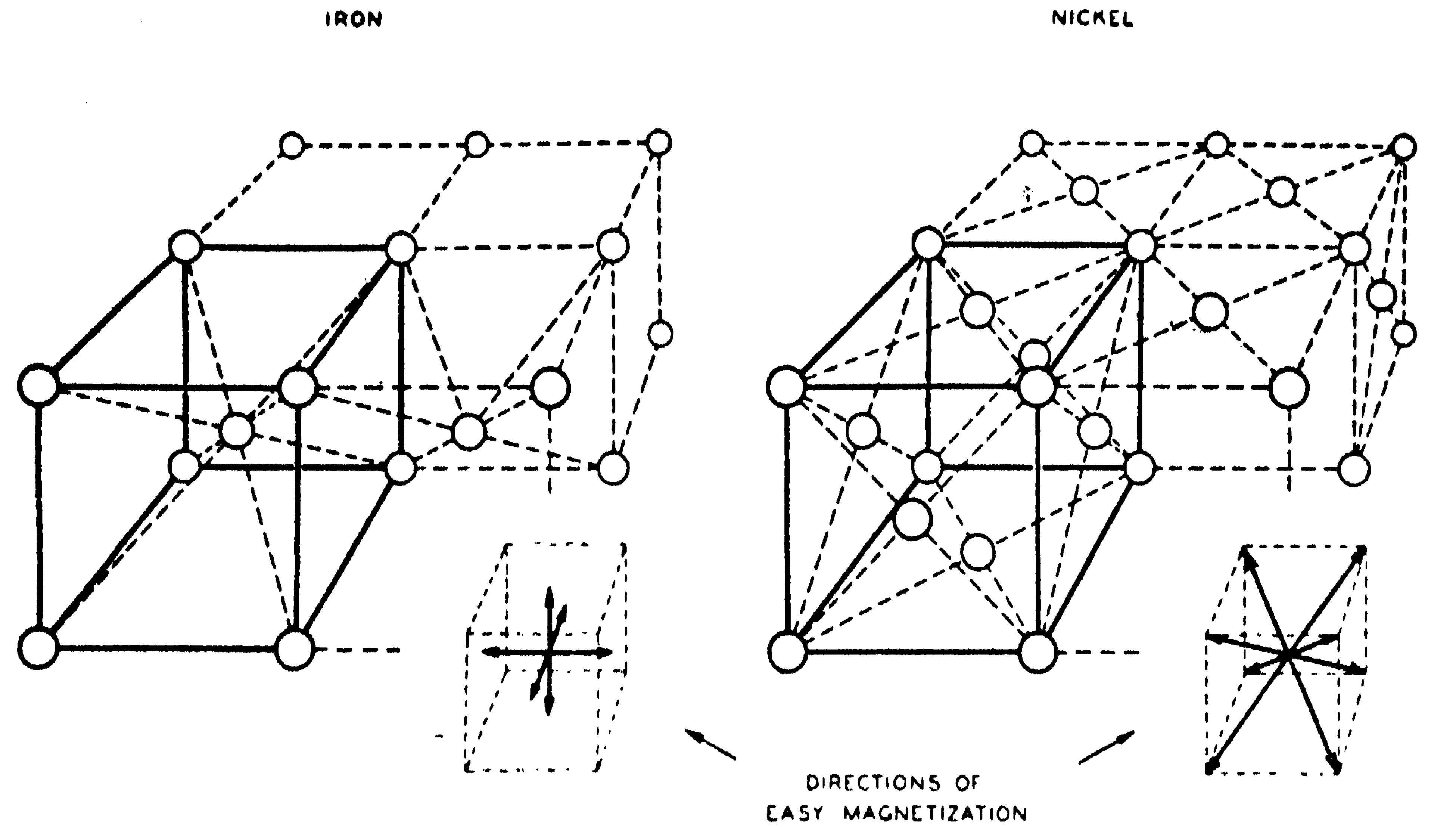


FIG. 2. THE POSITIONS OF THE ATOMS AND THE DIRECTIONS OF EASY MAGNETIZATION IN CRYSTALS OF IRON AND OF NICKEL.

In order to comprehend better the relative sizes of crystals, domains and atoms with which magnetic processes are concerned, it may be pointed out that a piece of ordinary iron a cubic centimeter in volume may contain about 10,000 single crystals, and that each crystal contains on the average 100,000 domains each with from 10^{14} to 10^{15} atoms.

It has been shown that the easy and hard directions of magnetization are due to the mutual magnetic forces between neighboring atoms. As far as the *electrostatic* forces of interaction are concerned, which cause neighboring atoms to be magnetized in the same direction as each other, any one direction in a crystal is as easy as another. The *magnetic* forces, however, are much stronger in some directions than in others, and it is these magnetic forces that determine in which particular direction the atomic magnets will point, and thus "select" the directions of easy magnetization in the crystal. The electrostatic forces are much stronger than the magnetic forces, but the latter alone are directional.

In a cubic crystal of iron the directions of easy magnetization are parallel to the cubic axes, that is, they are the six directions parallel to the edges of the cube which represents the structure. When such a magnetic material is unmagnetized, a portion of one of the crystals in it may be represented by the schematic Fig. 3(a). As shown, each of the domains, represented by the arrows, circles and crosses, is magnetized in one of the directions of easy magnetization and about one sixth are magnetized in each such direction as long as no magnetic field is present. When a field is applied in some direction as shown in Fig. 3(b), and gradually increased in strength, the magnetizations of the domains change one at a time so that their directions coincide more nearly with that of the magnetic field. When the field has been increased to such a strength that practically all the domains are oriented as shown in (b), a second process takes place: the magnetization changes slowly in direction until finally it is parallel to the field, and then

changes no more—the material is said to be saturated, as shown in (c).

Fig. 3 is drawn to illustrate the changes in magnetization that occur in a single crystal of iron. The iron which we ordinarily see, however, is composed of a great many minute single crystals, but the changes in magnetization that occur in each one of these crystals are just those which have been described, the magnetization of the whole polycrystalline material being the sum of the magnetization of the parts.

As already implied, the first or *sudden* kind of change of magnetization occurs in rather weak fields; for ordinary soft iron a field somewhat larger than the earth's field is strong enough to produce the situation represented in (b) The second or *slow* process takes place in fields from ten to a thousand times as strong as that of the earth. The typical way in which the magnetization of a material increases with the strength of the magnetic field is shown in Fig. 4. The parts of the curve which correspond to the sudden and slow changes are indicated.

The most definite evidence of the existence of domains and of the sudden or discontinuous nature of the magnetization in low fields is the so-called Barkhausen effect. A piece of magnetic material is wound with wire the ends of which are connected to a vacuum tube amplifier. When the magnetization of the material is changed, as by moving a permanent magnet near it, a rustling sound or a series of clicks may be heard in phones or in a loud speaker connected to the output end of the amplifier. Each such click is due to the sudden change in direction of magnetization in a domain, and from measurements of the sizes of the clicks we get our best estimate of the sizes of the domains. Additional evidence of the existence of domains and the changes that they undergo has been

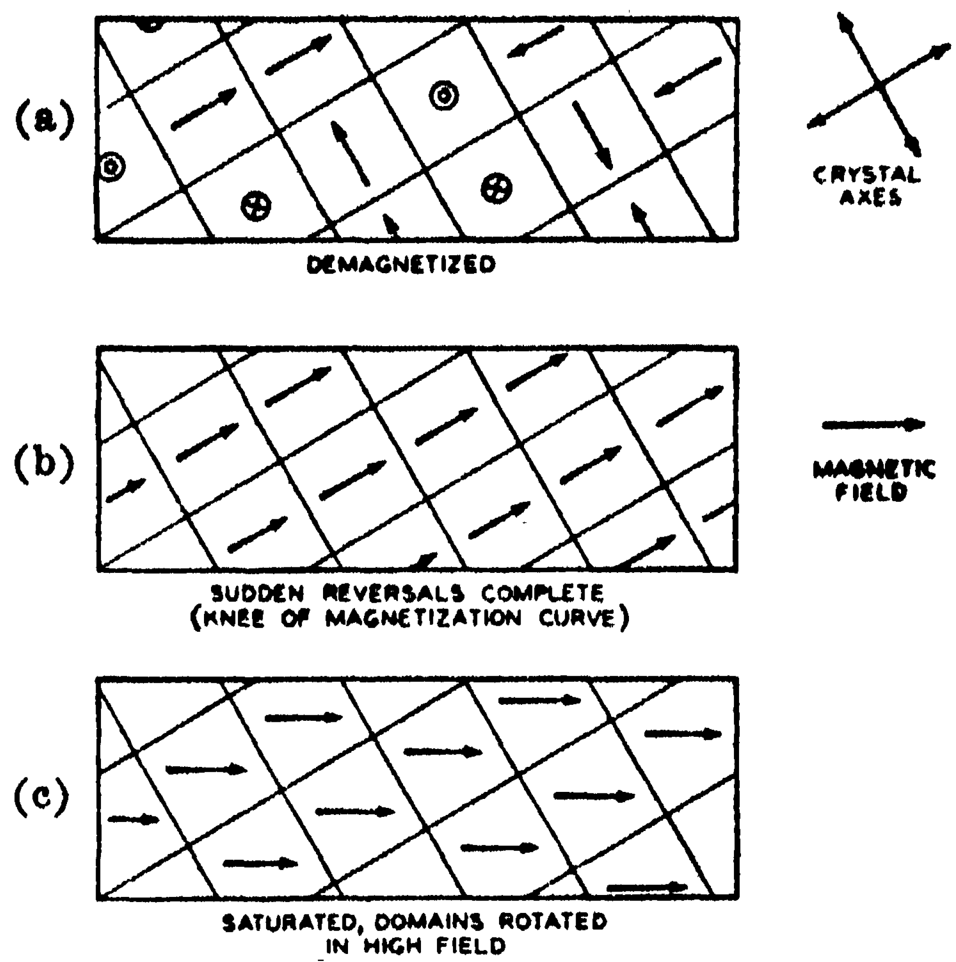


FIG. 3. DOMAINS IN A SINGLE CRYSTAL OF IRON. AS THE MAGNETIC FIELD INCREASES IN STRENGTH THE MAGNETIC MOMENTS OF THE DOMAINS FIRST CHANGE DIRECTION SUDDENLY (*a* TO *b*), THEN ROTATE SMOOTHLY (*b* TO *c*).

obtained recently by spreading colloidal iron oxide over the surface of a magnetic material and looking at it under a microscope. The regular pattern observed is similar in nature to the familiar one obtained when iron filings are sprinkled near a permanent magnet, the fine colloidal particles are necessary in this case

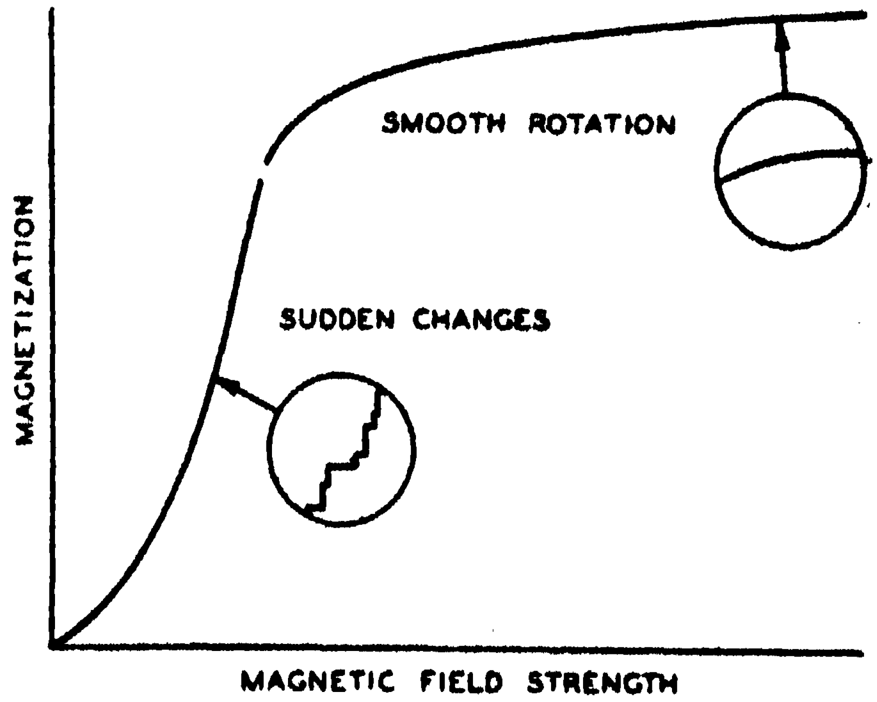


FIG. 4. A TYPICAL MAGNETIZATION CURVE. THE GREATER PART OF THE MAGNETIZATION TAKES PLACE IN SUDDEN JUMPS AS INDICATED BY A MAGNIFIED PORTION OF THE CURVE (CORRESPONDING TO *a* TO *b* OF FIG. 3), THE LATTER PART OF THE CHANGE IN MAGNETIZATION PROCEEDS SMOOTHLY (*b* TO *c* OF FIG. 3).

because the whole scale is small. This micro-pattern changes when the applied field changes, and the difference is attributed to the redistribution or reorientation of groups of domains. Such patterns are obtained only on magnetic materials and are found on them even when the material is unmagnetized.

Magnetic forces between atoms are also responsible for the various magnetic effects caused by straining a magnetic material, and for the converse effect, magnetostriction, which consists in a slight change in the dimensions of a magnetic material accompanying a change in magnetization. In commercial magnetic materials, strain is a very important consideration. To have high magnetic permeability, that is, to be easily magnetizable, a material must be annealed at a high temperature and the fundamental effect of this annealing is the relief of strains which were introduced in the material in its fabrication. Strains of a similar nature but on a much smaller scale are caused by the presence of certain chemical impurities, and the highest permeabilities can be attained only when these impurities have been removed. By such purification the permeability of iron can be increased to over 300,000, thirty times that of the iron ordinarily used in commerce for magnetic purposes. Recently by still more careful treatment, permeabilities of over 1,000,000 have been measured in a single crystal of permalloy, as shown in Fig. 5. Similar permeabilities have been obtained more recently in single crystals of pure iron and of iron containing 4 per cent. silicon.

For some purposes large strains are desirable, the larger the better. To make a good permanent magnet such as those used in loud speakers, great internal

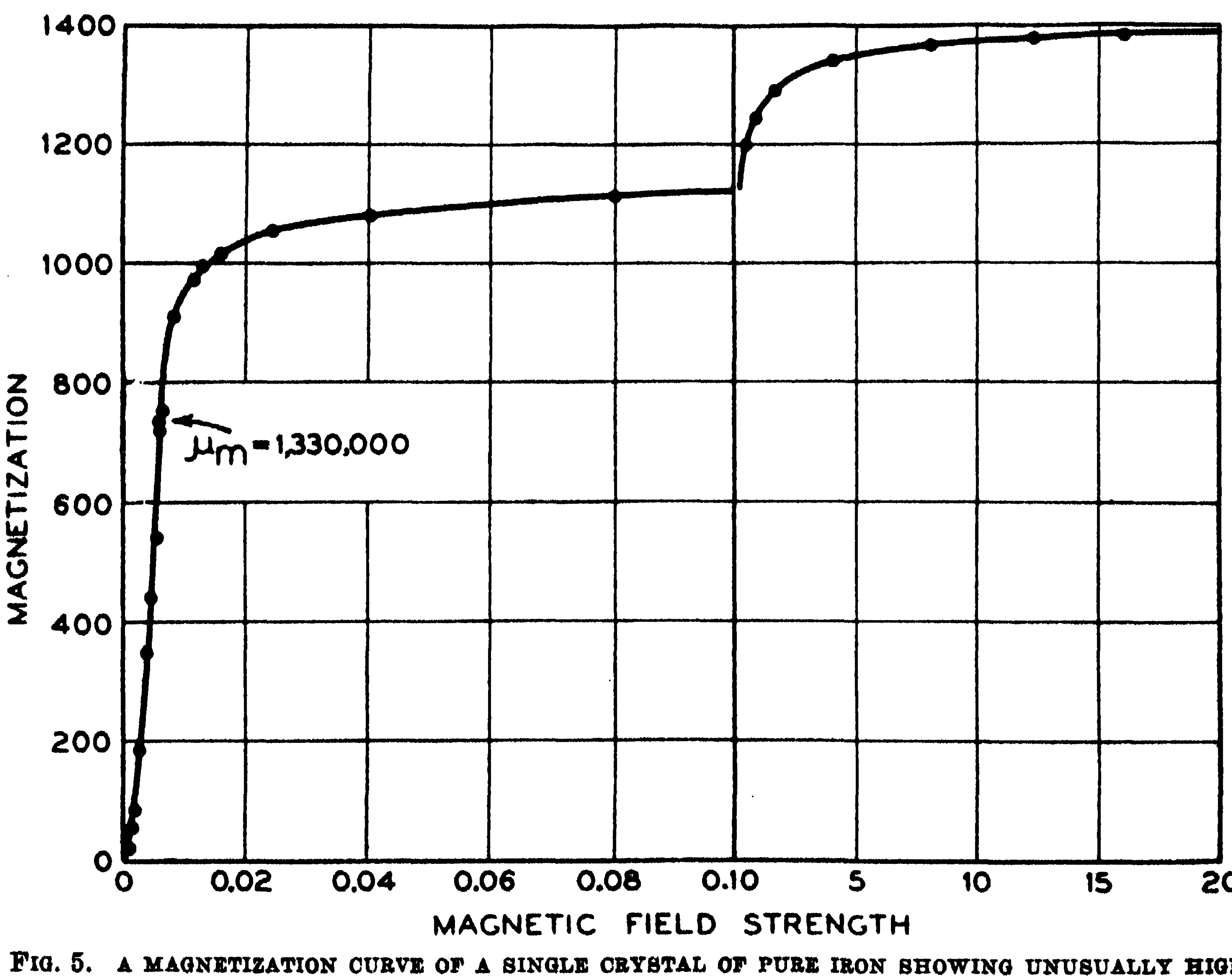


FIG. 5. A MAGNETIZATION CURVE OF A SINGLE CRYSTAL OF PURE IRON SHOWING UNUSUALLY HIGH PERMEABILITY, μ_m. (BY P. P. CIOFFI).

strains varying rapidly from point to point in magnitude and direction are produced by "precipitation hardening," the same mechanism as that which operates to produce the great mechanical strength in steel. Technically this permanency is often measured by the "coercive force," which in modern materials is about ten times that which was attainable a few years ago.

These internal strains are somewhat analogous to the ordinary mechanical strains that would exist in a group of rectangular wooden blocks piled together in a box. Due to the pressure of neighboring blocks, each block is held in a fixed position. This analogy may be used also to illustrate the fact that high internal strains are necessary for good permanent magnets. If each block represents a magnetic domain it can readily be understood that the greater the strain the more the mechanical force necessary to turn or twist one of the blocks in the middle of the pile, and so also the greater the magnetic force or magnetic field necessary to change the magnetization of a domain. Thus, when the strains are large, once a high magnetization is attained it is difficult to change, it is more permanent.

New materials and processes and new theories and explanations have come into existence recently and have mutually aided each other in their development. The new magnetic materials and processes may be expected soon to have a great influence on engineering problems, and the new theories and explanations have made it possible to write a connected story of magnetic theory.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

PRESSURE CONDITIONS OF 95 MILES IN EARTH EQUALLED

Using newly designed equipment man is now producing pressures in the laboratory comparable with those which occur nearly 95 miles within the earth! Professor P. W. Bridgman, of Harvard University, and experimentalist on high pressure, has just announced that his apparatus can now squeeze materials with a force of 700,000 pounds to the square inch.

If one calculates how much rock it would take to create this pressure (allowing a rock mass of 200 pounds per cubic foot) the answer comes out that 504,000 feet of rock are needed. This is a depth of over 95 miles within the earth. By comparison the deepest oil wells that man drills go only a little more than 11,000 feet into the earth. There they fail because the side walls squeeze the drill in a grip of rocky firmness.

The new pressures are over twice as great as any which Professor Bridgman has previously reported. This advance was made possible by a new design of his pressure chamber in which a tremendous pressure is not only present inside (to squeeze the test material) but also subjects the outside to a high pressure to keep it from bursting.

The little pressure cylinder is cone-shaped and is pressed against a steel collar simultaneously as the carboloy plunger presses on the test materials.

One of Professor Bridgman's new discoveries is that extreme pressure turns tellurium—ordinarily like sulfur and non-metallic—into a form which has true metallic properties. Under the severe pressure, too, Professor Bridgman was able to create new forms of bismuth and gallium. Ordinarily these elements behave abnormally, like ice, in that they contract on melting. Most elements expand on melting. By high pressure it was possible to make bismuth and gallium assume forms which also expanded on melting.

ARTIFICIAL RADIOACTIVE MATERIALS IN CANCER THERAPY

Investigators for some years have been smashing atoms in giant apparatus and turning nearly all the elements from one form into another by transmutation. With most of the elements now rendered radioactive at will, tests are under way to determine the biological usefulness of these new tools of science.

The newest instrument in the field of making artificial radioactive materials for biological experiments is the giant cyclotron of the Biochemical Research Foundation of the Franklin Institute. It is to be used to create quantities of materials for cancer therapy. It is quite conceivable that such materials, artificially prepared, may some day displace time-tried radium and radon in cancer treatment.

Among the benefits which would appear are: (1) the synthetic radioactive materials would have short lives and turn, in a few days, back into inert elements without effect on the body, and (2) almost any element seems capable of being rendered radioactive.

The significance of point 1 is that while "seeds" containing radon can now be "planted" within tumors the disintegration products can keep giving out

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

radiation long after the need for it is passed.

The meaning of point 2 is that a good way to treat cancer would be to find some element or chemical combination which would localize in the diseased tissue. If such a combination could be found the chances are that it would be made radioactive with the hope that it would give off radiation directly inside tumor tissue; rays that could destroy the cancerous growth.

This getting "inside" the tumor seems important, for external sources of radiation have an all-too-little specificity for malignant tissue. The rays can kill such tissue, but in so doing they also harm the surrounding healthy tissue.

SELECTIVE MOLTING AS AN ANALYSIS OF LIVING MATTER

N. A. Iljin, of the Soviet's Wool Laboratory, building upon the research of others, found last year that he could by single doses of thallium compounds make sheep shed their wool, leaving them naked as if they had been shorn. This is particularly effective for such sheep as those of the meino variety with uniform fine curling fibers.

Now he has discovered a way to apply the thallium molt to those less improved, more hardy sheep with mixed wool, whose fiber has been of little value because it is largely coarse and not uniform. If the thallium dose was small, only about 9 milligrams, the fine wool predominately fell out, if it was 12 to 13 milligrams both coarse kemp and fine fibers molted. This may possibly have economic importance.

There are difficulties, however, for thallium is a metal poisonous to plant and animal life. Iljin warns of "certain harmful by-effects" and in past years warnings have been issued here in America as to its danger. Numerous deaths followed use of thallium compounds in depilatory preparations. It removed hair with such great efficiency that those who used it became bald. Effective in fighting rodents and insects, even this use is discouraged because of the danger to human beings.

The Soviet investigator, however, has conducted his experiments more for the sake of biology than the wool industry. He calls selective molting in his sheep an example of the analysis of living matter by means of chemical action. Different doses of thallium promise to distinguish between sheep of different genetic strains. Selective molting is considered by Iljin "a proof of the possibility of a physiological distinction between morphologically different structures," a sort of chemical filter for unscrambling the mixtures blended by heredity.

LIFE AT VERY HIGH ALTITUDES

Life at very high altitudes, such as on the upper slopes of Mt. Everest, for example, is strangely different from ordinary living, it appears from the description given by Dr. C. B. Warren before the Royal Geographical Society in London. Dr. Warren was one of the medical officers of the 1936 Mt. Everest expedition.

Difficulty with breathing, of course, is one of the most noticeable changes and apparently is the first difference felt on ascending to higher altitudes. When resting, breathing goes on at about the normal rate, Dr. Warren observed, but the slightest exertion increases the rate, and the increase is way out of proportion to the amount of exertion. A short stroll presumably would leave a man breathing as fast as if he had been running a race. The breathlessness and the sudden awakening at night with a slight feeling of suffocation disappear, however, when climbers get used to the higher altitudes.

Another peculiar feature of life at high altitudes is the feeling of muscular weakness and lassitude.

"For the first few days at Camp III, I found that I was always longing to sit down and do nothing," Dr. Warren reported. "I can only compare the feeling to that sense of weakness which is experienced on first getting up after a long illness."

"A very distinct disinclination for serious mental work" was experienced at altitudes above 20,000 feet. Hearing and vision are less acute at high altitudes, according to some observers, but Dr. Warren did not notice these changes on the Everest expedition. Irritable tempers have also been reported as a feature of life at high altitudes, but Dr. Warren found that in spite of "provoking" conditions, no serious quarrels occurred.

Bracing mountain air is usually thought to stimulate the appetite. At really high altitudes, the opposite is apparently the case. Dr. Warren found that at 20,000 feet members of the party ate far too little, and consequently lost weight, although they thought they were eating enormously.

MAN'S FUTURE DEPENDS ON WHAT HE DECIDES TO EAT

Each of us is called on to make an important decision three times every day: What we shall eat for dinner, for breakfast and for lunch. Man's future depends very largely on what he decides to eat. That prediction comes from Dr. George R. Minot, of Boston, Nobel laureate, who discovered that liver would cure pernicious anemia.

Investigators have learned what should be eaten for good health and growth and even for long life and improvement of the race. Foods that are filling and energy-giving, like meat, potatoes and bread, are not enough. In addition, the diet should include what are called the "protective foods," because they protect us from serious ails such as scurvy and beri-beri and rickets, and from many minor degrees of undernutrition and poor health. Fresh fruits and vegetables and dairy products are protective foods. Statistics of food supply for the past two decades show a shift toward greater consumption of these protective foods. This shift is now being credited with having kept up the public health through the years of the economic depression. It is because of this shift, also, nutritionists believe, that boys and girls are entering college better developed at a slightly earlier age than their fathers and mothers.

Not enough of us, however, are making the three-times-a-day decision as wisely as might be. About half of us are eating a third-rate diet, a survey by Dr. Hazel K. Stiebeling, of the U. S. Bureau of Home Economics, revealed. The reason is not all a matter of pocketbook either. As might be expected, diets were very poor in families where the total food expenditure was \$85 per person per year. But at every spending level above \$100 per person per year some families succeeded in getting very good diets.

ROLE OF ENVIRONMENT IN MENTAL DISEASE

Fresh evidence of the power of social influences to bring on mental breakdown and disease has recently been given by the tragic story of five men who were playmates as little boys and who all are now patients in the same hospital for mental disease. One of these patients had enough understanding of the situation to bring it to the attention of the psychiatrist, Dr. J. McV. Hunt, of Brown University, who reports the circumstances in the current issue of the *American Journal of Orthopsychiatry*.

The five patients were members of a group of fifteen boys who grew up together in a poor neighborhood of Washington, D. C. Many of the boys had no parental guidance. When about ten years old they began to play around a slaugh-

terhouse and horse barns in the neighborhood and were initiated into sexual perversions by men around these two places. At the same time some of the boys regularly attended a neighborhood church where emotional revivals were frequently conducted. Some of these boys entered violently into the conversion experiences and resolved to give up their sexual perversions. Later, these resolves were broken. Each broken resolve made the boys feel more guilty, so finally they were almost continually miserable.

Some boys escaped this constant conflict. They were more closely watched by their parents and did not join the homosexual ring, or had anti-religious parents and so never went to church or revivals.

All the boys, and only those boys, who experienced the religious conversions and took part in the sex perversions subsequently were committed to institutions for mental disease. The conflict between the two influences was evidently too much for them, and mental breakdown and disease resulted.

Dr. Hunt points out that the community situation is not unique, although it does not in itself prove any theory of the cause of mental disease.

APES CAN LEARN HOW TO WORK IN COOPERATION

Pessimists despair of cooperative harmony among men. War, they declare, is inevitable. Common endeavor is an unnatural, artificial thing at variance with man's true nature.

Psychologists, unemotionally testing the truth of such claims, have stated their finding that nothing in man's nature exists to prevent world peace and cooperation for the common good.

Even apes can be taught to work cooperatively, it has been found in experiments at the Laboratories of Primate Biology, Yale University. The results, as reported by Dr. Meredith P. Crawford, are illuminating in connection with attempts to foster human cooperation. In his experiments, pairs of apes were taught to operate a food vending machine that one alone could not work.

(1) Motivation is all important. Unless the animal wants to work, it is useless to try any cooperative venture. The willing animal in such a case seems to know better than to bother with the unwilling one; he just abandons the project.

(2) Education is important, it was found. Both animals must be trained in the skills necessary for the task. Although sometimes the trained animal will make crude attempts to teach his untrained team-mate, the ape does not seem to make a good instructor. When both know what they must do, one takes the leadership and guides or encourages with gestures and cries, his associate in the task.

(3) Friendliness is important. Apes, like men, have pals of whom they grow very fond; with others they do not "click." For best working conditions, mutual regard is essential.

(4) Attitude of the cooperating animals is important. An individual ape is not always the leader or always subordinate. Some are more successful as the superior.

In one team, Bimba was leader and Bula subordinate. In another pairing, Bula became the leader of Beta. As leader, she increased her gesturing solicitation of help, and cooperation was speeded.

Desire, education, friendliness, leadership—are these the essentials also of human cooperation?

DRAW-CASTING COPPER RODS

One of the older arts of metallurgy is the fabrication of castings by pouring molten metal in a mold and allowing the whole mass to cool. Then the mold is broken away and one has the casting.

The method, of course, is a great advantage over the alternate task of trying to fashion the crude block of cold metal in the desired form.

The art of making castings, then, is old but there is a new technique which is only now coming into production. It is called draw-casting. Most people have never heard of it. It consists of drawing, directly from a bath of molten metal, rods and tubes of copper.

Dr. Byron E. Eldred, new president of the Engineers Club, New York City, and one of the nation's few remaining independent research scientists, is the inventor of draw-casting.

Dr. Eldred melts copper in a furnace which has one or more holes in the bottom. In each of these holes is inserted a copper rod that is going to be the "parent" of hundreds of feet of additional rod the same size. These parent rods are cooled by a surrounding water chamber and transmit their coolness up into the molten copper. Around each of their tips the melted metal starts to "freeze" and in turn becomes cooler. As the metal in the bath freezes, from the inside out as it were, the rods are pulled out and continually solidify more metal within the furnace.

The process, in one sense, reminds one of the old-fashioned method of making candles by dipping. At each dip the cool candle froze more crystals of wax and the candle continually grew larger and fatter. Since Dr. Eldred is not seeking "fat" copper rods he continuously pulls out the newly frozen copper at the end of the rods and gets continuous production that is a time and effort saver over present casting and rolling and drawing methods.

GRAVE OF AN UNKNOWN VIKING

Denmark has discovered its first Viking ship grave. The place where the ship lies, in a cornfield near the sea, has been roofed over and made an exhibit. All that is left of the barbaric, medieval burial has been treated by magic of modern chemicals to prevent it from disintegrating further.

The unknown Viking, thus brought into the spotlight, was perhaps one of the Danes who harried Britain and other European lands, in wild voyages of adventure. He lived about 950 A.D. in the time of that quaintly named king, Harold Bluetooth.

When this unknown Viking died, his ship was dragged up from the sea to a high place. His favorite horses and dogs were brought on board and slain. Attendants came laden with the Viking's weapons and articles he might need on the mysterious voyages of the future world. Then they covered the whole ship tomb under a mound of earth.

But the Viking did not rest in peace, long. His ship was visited by robbers, who carried off everything valuable they could find, and the body of the Viking besides.

When a Danish chemist arranged with the Danish National Museum to excavate the mound near his home, recently, he brought to light this story of medieval burial and robbery.

What remains is this: the foundation of the ship, a long, slim craft, 70 feet by a mere 10. The proud dragon head and the roof over the center long ago had caved in. But the excavators found iron spirals which made part of the dragon's mane, and iron rings belonging to the mast, and several thousand iron rivets of the ship.

Bones of 11 horses and four hunting dogs were found, 45 iron arrow-heads and a few small ornaments that show the splendor of accoutrements in the Viking world.

MAPUNGUBWE

A hill named Mapungubwe, on the

bank of Kipling's "great, greasy, grey-green Limpopo River," has been yielding graves and other clues to South Africa's past.

Awe-struck natives always said climbing Mapungubwe meant death. Their ancestors had buried treasures up there, and no one dared even to point to the sacred hill, in the wild region where it lay. But five years ago, a group of white men located the mill and found what they hoped for—buried treasure. It was, in fact, a skeleton with numerous ornaments of gold plate.

Fortunately, the treasure hunters were educated men, and one reported the find to the University of Pretoria. From then on, Mapungubwe has been probed by eager men, seeking a long-lost chapter of prehistory.

In an archeological volume called "Mapungubwe," Professor Leo Fouche, of the University of Pretoria, and others give a progress report. Excavations have dispelled native mysteries, showing that the hill was occupied by two separate peoples. After several centuries, they left. There was no fighting, no hasty departure, judging by lack of confusion in the ruins.

But before the people went down the hill for the last time, they apparently buried their sacred objects with their chief. One grave, nicknamed the Scepter Burial, contained a skeleton buried with a gold scepter in one hand. This episode in African prehistory happened in the Middle Ages, so the evidence mainly suggests.

Archeologists are now puzzled to know what these early Africans were like. Skulls they have seen are not true Negro type. They may represent a mixture, even including distant foreigners.

Urging extended digging to north and south of Mapungubwe, Professor Fouche declares that deeper knowledge of native failures and achievements in Africa's past may aid Britain in improving its relations with native subjects.

GERMAN SOYBEAN SUPPLIES

Germany, seeking economic self-sufficiency in raw materials and foodstuffs, especially in the all-important oils and fats, has undertaken the encouragement of large-scale cultivation of soybeans, hitherto imported in considerable quantities from Manchuria.

Systematic testing of the hundreds of known varieties of soybean is in progress, as well as breeding to produce new kinds better adapted to the German range of soils and climates. Werner von Haken, an agricultural economist, has blocked out areas where good results may normally be expected, and others where the chances are not so good.

Roughly a fifth of the total area of Germany is in the first-choice soybean regions. These are principally in the southwestern and central parts of the country. An additional two fifths is second-choice soybean territory, where success will be largely conditioned by local conditions and the skill of the individual farmer. The rest of the land, in the north and east and the mountainous south, is not recommended for soybean culture.

Herr von Haken's discussion contemplates large use of soybeans as human food. The Chinese have for centuries made a large variety of palatable dishes out of soybeans, which constitute the principal source of protein food for most of the population. Herr von Haken believes that crowded, blockade-threatened Germany would do well to follow the Chinese example.

Despite the fact that Manchurian soybeans can be imported into Germany more cheaply than they can be raised there, Herr von Haken feels that large-scale cultivation at home is desirable, even aside from questions of national policy. The imported soybeans, he points out, are a mixture of varieties and therefore do not cook uniformly. He also states that the home-produced soybeans are usually superior in flavor.

MARIE CURIE—HER LIFE WORK[1]

By Dr. FRANCIS CARTER WOOD

INSTITUTE OF CANCER RESEARCH, COLUMBIA UNIVERSITY

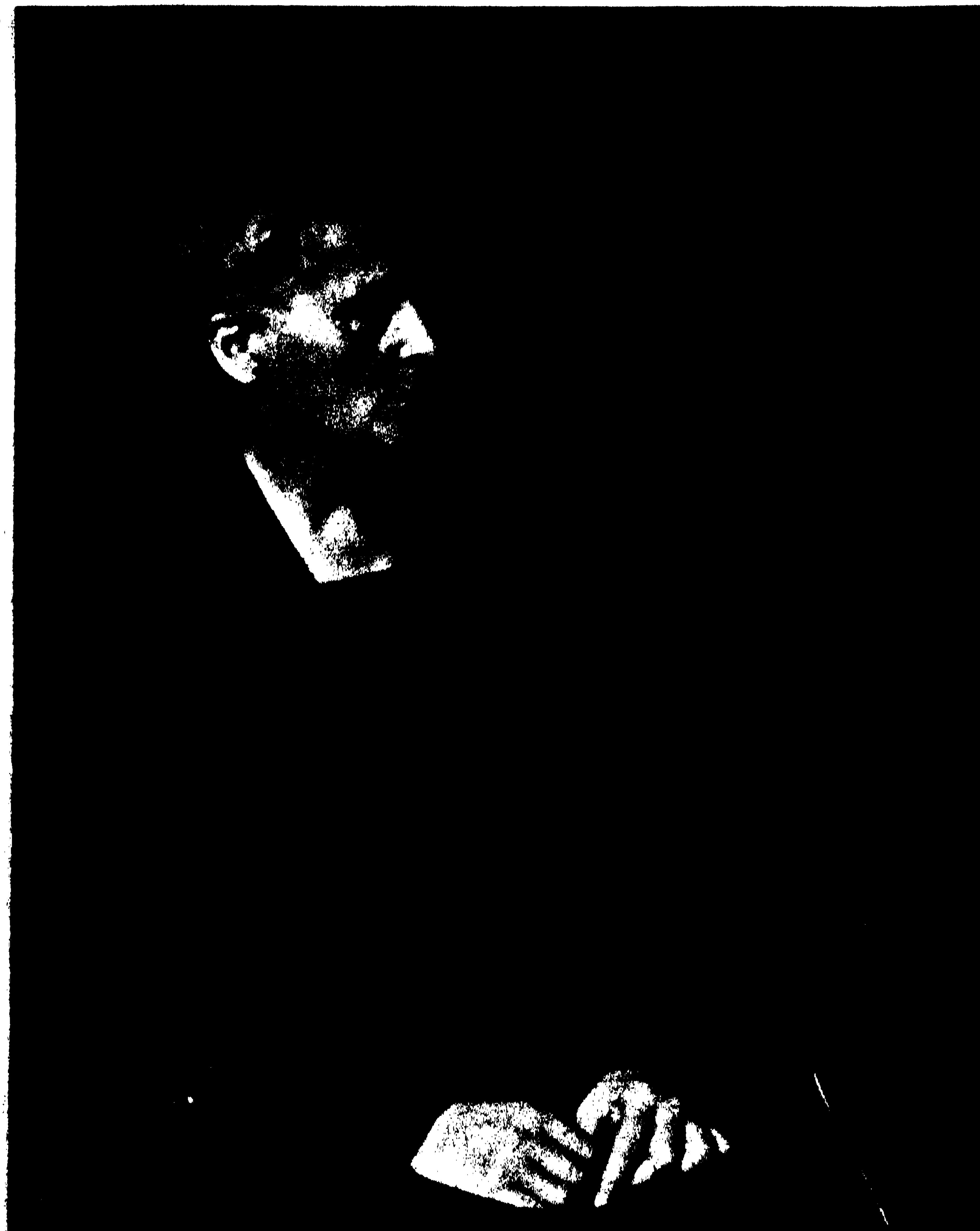
A STROLLER in the Latin Quarter of Paris in the winter of 1897 who happened to look into a small building used for storage on the rue Lhomond—that part of old Paris where the French preserve by the street names the glory of their scientists—would have seen a tall handsome man with a brown beard and a woman with a beautiful intellectual face gazing intently at some glass receptacles which were aglow in the darkness with a curious greenish light; even a thin vapor arising from some of the fluid in the basins was faintly luminescent. This couple was Pierre and Marie Curie, who after a day of hard labor in their workshop had returned after dinner, as they frequently did, to see that things were all right for the night and to wonder at this curious auroral glow that was produced by the hitherto unknown element, radium, which they were in the process of isolating from the ores of uranium. This faint luminescence was due to the alpha rays which the radium and its emanation gave off, bombarding the atoms of the air, changing their chemical nature and exciting their electrons, and the Curies were observing the birth of the world of the infinitely little and the dawn of the new alchemy. Though they did not know it, their discoveries were to revolutionize the opinions of 2,000 years, completely transform modern physics, aid astronomers in their study of the stars, restore to life and health thousands of human beings, and inspire a host of investigators along innumerable lines of study in wholly new fields. It is of interest to discuss briefly what led to this remarkable discovery, for in science no one stands alone for if Roentgen had not discovered in 1895 the rays which bear his name, the name of the thirty-year-old Marie Curie might never have been known to fame.

About the year 1890 physics was supposed to be more or less finished, for it was felt that all the important laws had been discovered, and the only thing remaining was to measure the known phenomena more accurately. It is true that certain scientists in England and Germany were studying the luminous bands and other phenomena which occur when a fairly high-voltage electrical current is passed through a glass tube containing various gases at low concentration. Faraday and Crookes were two who had spent time on this subject without casting much light on its nature. About 1890 an English physicist, J. J. Thomson, studying the effects of the transmission of electricity through rarefied gases, began to make observations which pointed to the fact that the explanation of the luminous phenomenon must be that under the influence of electricity the gas in these laboratory aurora is broken down into electrified particles, for the colored streamers were deflected by a magnet or an electric current outside the gas-containing tube, as Plücker had described in 1858.

It was while working with such a tube in 1895 that Roentgen noticed that photographic plates lying on a table nearby were fogged, and in a few months the discovery of x-rays was made. He, as Plücker in 1858 had noted, saw that the glass of the tube assumed a bright greenish color while the current was passing, and it was thought at first that this greenish color was the source of the radiations.

Poincaré, the famous French mathe-

[1] Read at a memorial meeting held at Columbia University on January 20, 1938.



To Dr Francis Carter Wood
with my best wishes
M. Curie.
November 8, 1929.

matician, showed the first x-ray pictures taken by Roentgen, at a meeting of the Paris Academy of Sciences in January, 1896, and in the discussion which followed made this same suggestion as a possible explanation in reply to a question by Henri Becquerel. The father of Becquerel had been a famous chemist, and the son possessed a considerable supply of uranium salts which had come into his possession after his father's death.

Uranium salts give off a greenish phosphorescence when exposed to light, so Becquerel covered some photographic plates with black paper, laid the uranium salts on them together with some metal objects and, to his astonishment, found that he had a Roentgen shadow picture. Being a scientist, he tried some uranium which had not been exposed to light and found that it photographed just as well. Then he took some fresh samples of very pure, recently prepared uranium and found that it did not photograph. Becquerel recognized that the photographic effect must lie either in the atoms of the uranium or in a contaminating substance present. To-day we know that the uranium breaks down in the course of years into radioactive substances. For a long time these rays were called Becquerel rays. Becquerel was unable to continue these investigations and suggested, late in 1897, to Pierre and Marie Curie, who shortly before had been married, that they follow up this discovery and find out what was the substance in uranium which possessed photographic capacities.

This selection had a touch of genius in it, for Pierre and Marie Curie combined that persistent and clear-sighted intellectual energy which is so necessary for scientific discovery. They were poor, struggling to do work under disadvantageous conditions, and gladly turned to this new field where Pierre Curie's knowledge of physics and Marie Curie's knowledge of chemistry were needed to solve the problem. In 1898 they announced the discovery of radium.

There has been much discussion as to the part which each played in this discovery. Marie Curie has always said that it was a combination of two closely related minds. It was her duty to do the arduous chemical analyses which were necessary to find the minute traces of radium in the ores with which they worked. They tested all the minerals in the college collection and found a few which had photographic power and also were capable of ionizing the air about them so that it would carry a minute electric current instead of acting as a very perfect insulator, as does ordinary air. These ores were chiefly those containing uranium. It was Pierre Curie's share, as a trained physicist, to take each substance—and there were over thirty known elements in the uranium ores—and determine, with an apparatus which he had invented some time before, the amount of ionization that each sample produced. Thus, as they eliminated metal after metal, they finally found that mixed with bismuth and barium were minute traces of intensely ionizing substances. The first was polonium, the second radium.

The quantity of current which flows when the ionization is produced is a measure of the radioactivity of the element. Radium salts are never sold by weight, but by the ionization which they produce as compared to a standard, and the x-ray used in the treatment of cancer is also measured by this means. In this phase of their work they fell back upon the discoveries which had been made in the past showing that not only x-rays made air a conducting medium, but that all gases became conducting when a current of electricity was passed through a glass tube containing a rarefied gas, thus returning to the early work of Faraday and others who had noted this phenomenon.

Now we know that the currents through

these tubes or through what is called an ionization chamber are produced by the separation from a gas of the electrons, a swarm of negatively charged particles so minute that we shall never be able to see them, which themselves being charged with electricity or, according to the modern view, consisting of an electrical charge, are able to transfer a current by moving from one pole to another. Faraday many years before had brought forward a similar idea to explain the conduction of electricity through fluids and the basis of all electrical deposition of metals which had long before reached a practical development as every piece of Sheffield plate testifies, for the silver in a solution of silver salt is carried from one pole and deposited upon the copper, which forms another pole. To-day we know that x-rays are produced by the beating of these electrons upon the surface of a metal, which so perturbs the atoms of that metal that they radiate x-rays, just as an electric current in the ordinary lamp bulb heats the filament and makes it give off electrons, as Thomas Edison showed in 1883 without knowing the explanation.

Thus Marie Curie by her chemical discovery of the element radium inaugurated what may be called modern physics, and it must have been to her a marvelous satisfaction that her daughter, Irène Joliot-Curie, has followed in her footsteps, making one discovery after another, which would render the name Curie imperishable had her mother never been famous. But it has been granted to no other woman so to revolutionize by a single discovery the whole subject of atomic physics.

When Pierre Curie in 1903 found that radium gave off heat, many of the theories of physics, especially that dealing with the conservation of energy, seemed to be shattered, but shortly afterward it was shown that this heat was produced by the breaking down of the atoms of radium, and the heat production could be accounted for by the slow, spontaneous destruction of this newly discovered element which in some 1,700 years loses half of its substance. The final stage which this breakdown reaches is lead, a lead which can not be distinguished from the ordinary plumber's lead, except by the most refined methods of analysis.

In passing, it may be said that this fact has been used to measure the age of the earth, for the minerals which contain uranium also contain lead and the amount of this lead gives a measure of the number of years that the uranium has been in existence. Hence, like the rings of the great redwood trees in California which show that they are the oldest living creatures, so the amount of radium lead in minerals points to millions of years of life of an ore in which the original uranium has been slowly changed through a series of breakdowns into lead.

The first radium obtained was very impure, and after 1898 Pierre Curie interested himself in the physical properties of this new substance and discovered that it gave off particles which could pass through air for a distance of one to two inches and then suddenly stop. These are now known as the alpha particles from radium and are actually electrified atoms of helium gas. The gamma and beta rays, the latter being negatively charged particles, were found by others, chiefly Rutherford.

Marie Curie then devoted herself to the separation of large quantities of radium from the residue of many tons of uranium ore from Joachimstal in Bohemia, which were placed at her disposal by the Austrian government. After years of hard work requiring a most laborious series of chemical separations and crystallizations of the impure product, she finally succeeded in making a small quantity of absolutely pure radium, the chemical properties of which she studied. She also prepared sealed tubes containing

carefully measured amounts of the pure salts which are deposited in the various bureaus throughout the world, including the Bureau of Standards in Washington, to serve as standards for the measurement of radium, just as the standard meter and standard yard are deposited and used for the checking of accurate measuring instruments.

In the meantime, a host of investigators, including the famous Lord Rutherford, who died only a few months ago, began to investigate this profitable field. The Curies had noticed in 1899 that all the apparatus and even the walls of the room in which they worked became radioactive. It was soon found that radium gave off a gas which is now known as emanation or as radon. This gas is really the active substance which characterizes radium, for, if the gas is pumped off, radium ceases to radiate, but in the course of a few days regenerates more radon, which can again be pumped off and used for practical purposes, for a great deal of the treatment of cancer is done with radon rather than with radium. This radon gas has a very short life, losing half of its value in a little over three days.

Further studies showed in the course of the breakdown of radium that a large number of products were obtained, some with an extremely short life measured in thousandths of a second, others which lasted for millions of years. In the uranium-radium family there are sixteen known members, the last being lead. It was soon found that thorium also possessed radioactivity, and the thorium family has thirteen known members, ending again with lead. Later an actinium family was found, also of many members, and its termination is also in lead. But this was the work of other hands.

Others also invented elaborate theories for the constitution of matter based upon Marie Curie's discoveries. We believe for the moment that an atom of matter is composed of a central nucleus, which contains neutrons and fragments of hydrogen known as protons, and around this as a center rotate the electrons, one for hydrogen and up to 92 for uranium, the metal with the highest atomic weight. The Curies vaguely dreamed of this celestial system with a central sun and surrounding planets, and Irène Curie just missed the discovery of the neutron by a few months. The central mass of neutrons and protons determines the nature of the element and the electrons control its chemical reactions. The electrons can be pulled off by exposure to Roentgen or gamma rays and heat. This does not change the actual chemical nature of the substance, for the atom which has been stripped of some of its electrons collects these quickly from neighboring atoms and becomes normal again. In a gas this recovery takes only a few minutes. But Lord Rutherford showed in 1919, that if alpha particles from radium are allowed to play upon nitrogen gas some of the nitrogen is destroyed and changed into oxygen and hydrogen. Apparently the helium particle is able to break into the center of the atom and change the atomic weight, for nitrogen has an atomic weight of 14 and the oxygen produced of 17. Helium with an atomic weight of 4 and nitrogen with 14 makes an atomic weight of 18 against the oxygen with 17, leaving a missing weight supplied by hydrogen with an atomic number of 1. Both helium and hydrogen can be found in the sealed tube originally containing only nitrogen. This was the first artificial production of new elements and is the field in which Irène Curie has made herself famous.

Whether the radium which Marie Curie discovered will ever be produced artificially by some such process is as yet unknown. Probably it will be found that the amount of energy used up is so enormous that the transformation must remain a laboratory experiment, but Pro-

fessor Ernest O. Lawrence, of California, has produced several pounds of radioactive sodium by bombarding ordinary salt with atomic bullets, which has certain interesting uses in that if a small quantity is placed on a person's tongue and an electrical machine attached to his foot, it will be found that this sodium is in a few moments in the general circulation, thus testing the speed of absorption. Radioactive iron is being used to study the way in which anemia is cured by iron, and a host of interesting problems have developed from this work. All these things are mentioned merely to show the marvelously fertilizing effect of a single important discovery.

In the light of all these astonishing events it seems as if the pioneer work of Marie Curie was very simple, but this is because the facts have become a part of everyday knowledge and it is the gift of the genius such as this woman possessed to interpret the results of simple chemical analyses and to infuse into dull decimals a life of the spirit. Thousands of chemists could have done the analytical work which she did as she employed merely text-book methods, but in her mind lay the power to conceive theories to explain not only what had already been discovered but to open paths for further investigation. In many instances she was unable to carry these on in person, but they were immediately seized upon by others who used the ideas which she had developed to make important discoveries.

Her mind was an extraordinary one. She had no interest in people in general or for the ordinary matters that fill the minds of so large a proportion of the world. She cared nothing for names and titles, as some amusing incidents related in a recently published biography by her daughter, Eve Curie, show. She cared only for a few friends and her scientific work. In this field she had the power of enormous and prolonged concentration on a problem. In her later years, despite serious ill health, she worked in a variety of fields and contributed to all of them. She studied the causes underlying the destruction of cells by radium, for example. During the world war, when her laboratory was closed, she applied herself to the practical use of x-rays and did valuable work in organizing and directing a field system of portable x-ray machines by which surgeons could be guided in the treatment of injured soldiers. It must have greatly pained her, who longed to benefit the human race by her labors and refused to patent or accept money for her method of refining radium, to know that the discovery of radium, which has meant so much for the saving of human life, was also used extensively to coat luminous tapes to guide soldiers through the barbed wire entanglements of the battlefields and to illuminate gunsights in order that men might shoot each other with greater facility.

Her direct contributions to the treatment of cancer were few. She was immensely interested in the work of the Curie Institute under Dr. Claude Regaud, for which she was responsible, and was of great help in teaching the staff the technique of preparing and measuring the radium they were using.

It was interesting to see her mind at work. As she passed through the great Physical Laboratories of Columbia University on her first voyage to America she must have thought of the abandoned storehouse in which she had worked. While nothing interested her but some of the subjects with which she was familiar, she would immediately stop and discuss any work in her own field with a member of the staff, wholly forgetful of time, appointments and the friends who wondered why she did not turn up for lunch, concentrated and interested in the new things that she was able to see in other people's investigative labors. There was not one atom of jealousy in her nature.

That she was a genius there can be no

doubt. True, all genius is aided by circumstances and she might have remained a teacher of chemistry in a French school if it had not been that Becquerel made and tested an erroneous theory, and as a result an opportunity was given to her to investigate a new field of science. But it is true also that many others were working in the same direction, but had failed to accomplish anything.

The argument has been made that because simultaneous discoveries are not infrequent in science genius is merely a question of mass action and if only a sufficient number of persons work on a problem, the discovery will be achieved. But since the pioneer work of Plücker in 1858 innumerable persons had run an electric current through an evacuated glass tube and studied the phenomenon which ensued, though it was not until 1895 that Roentgen found that every such tube gave off x-rays. It is related that one English scientist of great ability noted that his photographic plates were fogged in the neighborhood of such a tube, but instead of searching for the reason, he complained to the maker of the plates that they were defective and obtained a new box. Roentgen had the flash, the intuition, if you will, which made him find out why his photographic plates were fogged. So Marie Curie had the intuition which led her to devise the hypothesis that it was the breaking-down of the atoms of uranium which caused it to give off radiation. Without this working hypothesis radium might not have been discovered for another hundred years.

After her husband's death in 1906 Marie Curie was appointed to his chair of radio-physics in the Sorbonne and continued his lectures. In 1910 she published an important work, a "Treatise on Radioactivity" which summarized their labors and those of others up to that time. Later she wrote a charming memoir of her husband, which is too little known, though an admirable translation has been printed in this country. She also published a book on "Radiology and the War" which was drawn from her experiences in organizing a field radiological service for the French army. She continued her scientific researches despite continued ill health and published many short papers on various topics. Her laboratory became a center for research students from all parts of the world.

Much has been made, and I think too much, of the difficult circumstances under which the Curies worked, their poverty and the lack of appreciation in France in the early period of their discoveries, but truly they lived an ideal life. They believed, in spite of her dreams for the emancipation of her native Poland and their desire to help humanity, that they were powerless to change the social order; that if they had had the power they would not have known what to do, and so in working without understanding they would never be sure that they were not doing more harm than good by retarding some inevitable natural evolution. In science, on the contrary, they felt they could accomplish more with their lives than in any other direction; that the field here was more solid and obvious, and however small a territory it might be it was truly their own possession. Marie Curie writes of her early days in Paris: "This life, painful from certain points of view, had for all that a real charm for me. It gave me a precious sense of liberty and independence. If sometimes I felt lonesome, lost in the great city of Paris, my usual state of mind was one of calm and great moral satisfaction. All that I saw and learned delighted me. It was like a new world opening to me, the world of science which I was at last permitted to know in all liberty." Of the abandoned shed which was the best laboratory the School of Physics could give them she writes: "Despite the exhausting work it

was in this miserable old shed that we passed the best and happiest years of our life, devoting our entire days to our work. I shall never be able to express the joy of the untroubled quietness of the atmosphere of research and the excitement of actual progress with the confident hope of still better results. The feeling of discouragement that I sometimes felt after some unsuccessful toil did not last long and gave way to renewed activity. We had happy moments devoted to a quiet discussion of our work while walking around our shed."

Another and far different person has described the same sensation. "I do not know how far it is possible to convey to anyone who has not experienced it the peculiar interest, the peculiar satisfaction, that lies in a sustained research. It is a different thing from any other sort of human effort. You are free from the exasperating conflict with your fellow creatures that, for me, is its peculiar merit. Scientific truth is the remotest of mistresses. She hides in strange places; she is attained by tortuous and laborious routes. She is always there, winning you to her, and she will not fail you. She is yours and mankind's forever. She is reality. You cannot change her by advertisement or clamor nor stifle her in vulgarities. Things grow under your hands when you serve her, things that are permanent as nothing else is permanent in the whole life of man. That, I think, is the peculiar satisfaction of science and its enduring reward."

So I think that if Marie Curie had been asked in her last days, as she looked across to the sunlit mountains of Savoy from her room at the sanatorium at Sancellemoz, what her life had been, she would have replied that it had been full of human affection and companionship with one whom she loved, full of the joys of research, of hard work and of final achievement, crowned at last with the highest of human rewards, the admiration by the few great minds capable of understanding the superb nature of those discoveries which were hers and render her name imperishable as long as the human race exists.

THOMAS ALVA EDISON
FEBRUARY 11, 1847—OCTOBER 18, 1931.

THE EDISON MEMORIAL TOWER

The Edison Memorial Tower, a one hundred and seventeen foot concrete monolith on the top of which is a fourteen-foot beacon, was dedicated on February 11, the ninety-first anniversary of the inventor's birth, at Menlo Park, N. J., where Thomas Alva Edison invented the first incandescent electric light.

The tower looms as the highest discernible object for many miles. Surmounting the 117-foot, 8-inch concrete-slab structure is a 13-foot, 8-inch replica of the original incandescent lamp which, illuminated nightly, can be seen for a distance of several miles, serving as an airplane beacon. The foundation of the tower consists of a reinforced concrete pad two foot six inches thick under the entire structure. The space between this pad and the floor of the entrance room to the tower, containing the "Eternal Light," was back-filled with earth for the purpose of adding weight to increase its stability against wind pressure, in the same manner as the keel on a sailboat is provided to counteract the pressure of wind on its sails. The tower is designed for pressure of wind at a velocity of 120 miles per hour. In its construction, which consumed slightly less than eight months, there were used approximately 1,200 barrels of Edison Portland cement and 50 tons of reinforced steel.

The large bulb on the top of the tower was cast by the Corning Glass Works, which fifty-nine years ago, in 1879, furnished from a sketch the first commercial electric light bulb. The replica bulb contains 153 separate pieces of amber tinted Pyrex glass, two inches thick, set upon a steel frame. The bulb is five feet in diameter at the neck and nine foot two inches in diameter at the greatest width and weighs, without the steel frame on which it is placed, in excess of three tons. Inside this Pyrex glass bulb are four 1,000 watt bulbs, four 200 watt bulbs and four 100 watt bulbs. A duplicate of each is so arranged as automatically to cut in should its companion bulb fail. The glass in the Pyrex bulb was placed on its steel frame at the Corning Glass Works, Corning, New York, and then, after being numbered, each piece was dismantled, packed and shipped to Menlo Park, where the work of permanent assembly atop the tower itself was undertaken early in December, 1937.

On seven of the eight sides of the octagonal base are bronze tablets inscribed with descriptions of major Menlo Park inventions. In front of a bronze and glass door in the eighth side, in the concrete base of the tower, is buried a copper box containing, along with several documents, copper plates on which are inscribed the names of the officers and members, past and present, of the Edison Pioneers and the names of the officers and directors of The Thomas Alva Edison Foundation, Incorporated, together with the names of the technical bodies which they represent. The use of copper, apart from its ability to withstand the elements over the years, is in recognition of Edison's inestimable contributions to that industry's growth through the enormous demands for copper metal made necessary by the expansion of the electric light and power industry, in the creation of which Edison was so prominent a factor.

Emblematic of the invention on this spot in 1877 of the phonograph, is a sound system designed and manufactured by the RCA-Victor Company of Camden, N. J. Electrically transcribed phonograph records can be broadcast from the top of the tower ninety-six feet above the ground. There, beneath the huge lamp, are decorated grilles, behind which are wide-range, high-powered, loud speakers.

—*Wide World*

THE EDISON MEMORIAL TOWER

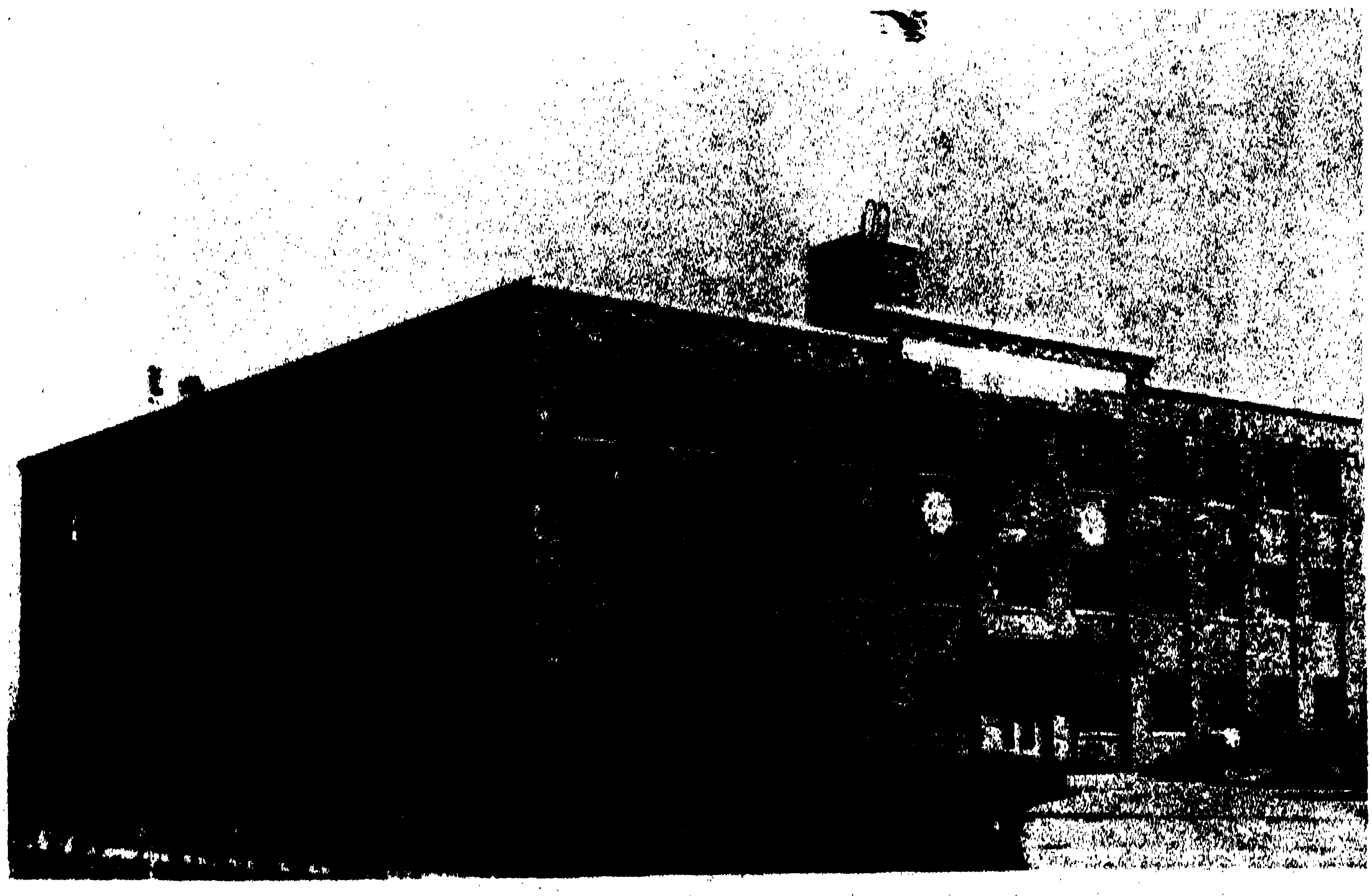
THE DEDICATION AT MENLO PARK, N. J. A GENERAL VIEW SHOWING THE GROUND AROUND THE MEMORIAL, PHOTOGRAPHED DURING SERVICES ON FEBRUARY 11.

The speakers are designed to transmit chimes, music of all kinds, as well as speech, over a radius of two miles. The group of specially designed, heavy duty amplifiers, with all controls, is located in the operating room in the tower. Here are also installed the transcription turntable and the lateral and vertical sound heads for reproduction of standard or special recordings of all types. This transcription turntable is the highest quality available and, in combination with "hill and dale" (vertical) recordings, which Edison invented and always used, provides extremely faithful reproduction of any type of music or speech. Part of the general installation is a group of eight loud speakers located thirteen feet from the base of the tower; these are designed particularly for speech reproduction over a radius of at least one hundred and fifty feet. They are equipped with a high duty, portable microphone for use at locations provided with connections to amplifiers. Provision has been made for any addition of electric organ or electric carillon, as well as for Westminster chimes, in combination with a time clock, for striking the hour, half hour and quarter hour.

THE MICHIGAN STATE LABORATORY

Recently, at Lansing, one of the country's finest publicly owned laboratories was formally opened by the State of Michigan. At that time, workmen of the Works Progress Administration had almost completed construction of its last unit. Known as the Michigan State Diagnostic, Research and Control Laboratory, it provides facilities for the state's research and laboratory work and has attracted wide attention to findings resulting from extensive experiments carried on by its staff.

The laboratory was opened in 1923

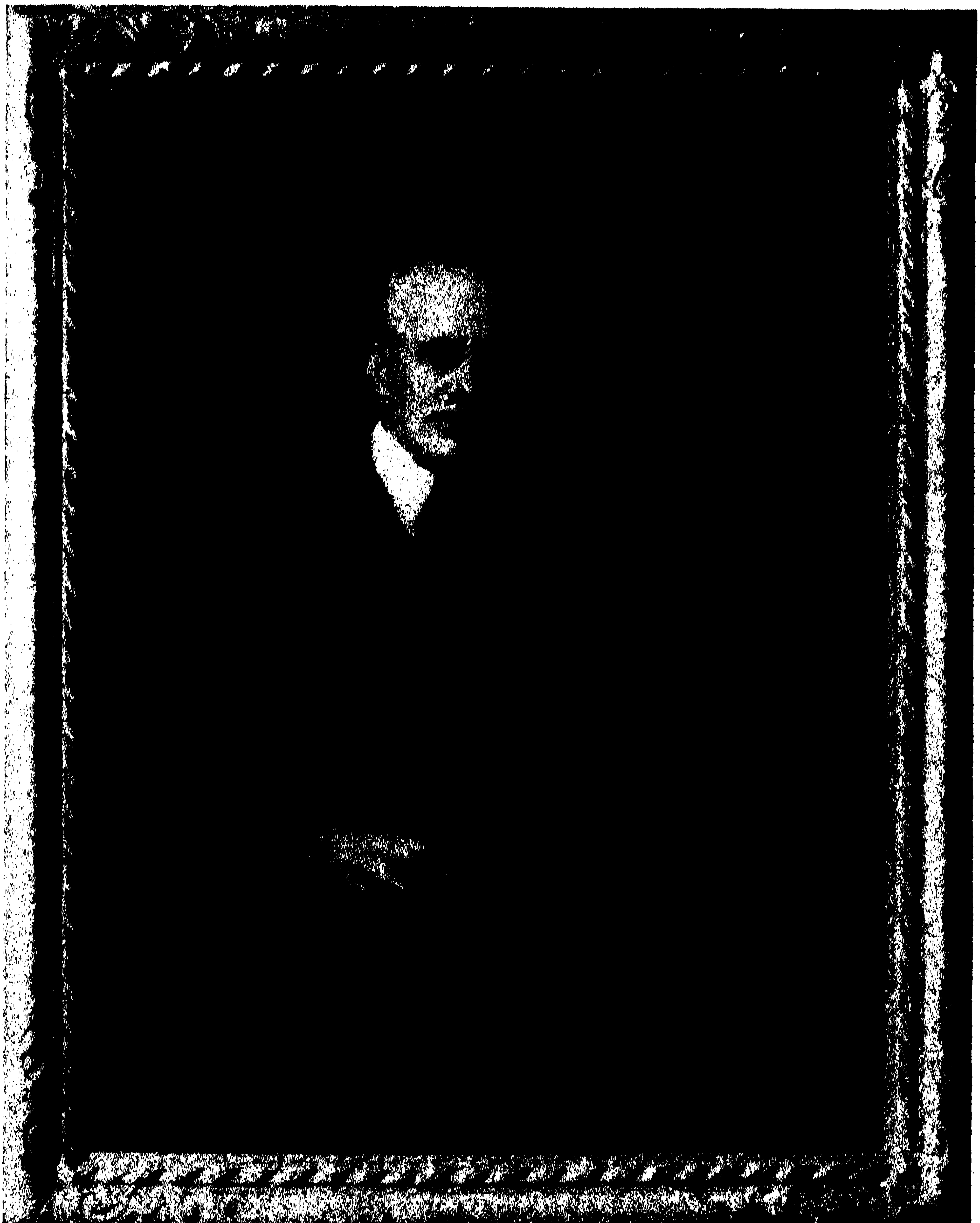


THE MICHIGAN STATE DIAGNOSTIC RESEARCH CONTROL LABORATORY

THE BUILDING, WHICH WAS RECENTLY COMPLETED BY THE STATE OF MICHIGAN IN COOPERATION WITH THE WORKS PROGRESS ADMINISTRATION, HOUSES THE ADMINISTRATIVE OFFICES, THE QUARTERS FOR THE CHEMICAL LABORATORIES OF THE MICHIGAN STATE DEPARTMENT OF AGRICULTURE AND THE PHOTOGRAPHIC DIVISION OF THE MICHIGAN STATE HIGHWAY DEPARTMENT.

HENRY HERBERT DONALDSON

WHO HAS DIED AT THE AGE OF EIGHTY YEARS, HAS LONG BEEN A LEADER IN ANATOMICAL SCIENCE, HAVING BEEN FOR MANY YEARS PROFESSOR OF NEUROLOGY AT THE UNIVERSITY OF CHICAGO AND LATER A MEMBER OF THE WISTAR INSTITUTE OF ANATOMY AND PROFESSOR OF NEUROLOGY AT THE UNIVERSITY OF PENNSYLVANIA. HE IS BEST KNOWN FOR HIS WORK ON THE NERVOUS SYSTEM, WITH SPECIAL REFERENCE TO GROWTH AND THE CHANGES DUE TO AGE.



GEORGE ELLERY HALE

IN WHOSE DEATH THE WORLD LOSES ONE OF ITS LEADING ASTRONOMERS. HE HAS BEEN CALLED "THE GREATEST BUILDER OF AMERICAN ASTRONOMY," HAVING BEEN RESPONSIBLE FOR THE ESTABLISHMENT OF THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO, THE MOUNT WILSON OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON; AND THE NEW OBSERVATORY ON PALOMAR MOUNTAIN OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY. HE IS DISTINGUISHED FOR HIS OWN RESEARCH, ESPECIALLY ON THE MAGNETIC FIELD OF THE SUN, AND HAS BEEN A LEADER IN MANY MOVEMENTS FOR THE ADVANCEMENT OF SCIENCE AND CIVILIZATION.

with a one-story brick building containing about 2,000 square feet of floor space, with small adjacent buildings for animals used for experiment, and has been expanded until it now is a half-million dollar plant, complete in every respect.

The new administration building, containing about 33,000 square feet of floor space on its three floors, provides facilities for the State Health Department on its first and second floors, an office for the director and two rooms for the photographic division of the State Highway Department. The third floor is devoted to the chemical laboratory of the State Department of Agriculture, operated under the direction of W. C. Geagley, state chemist. Three animal houses, tripled in capacity since 1934, are constructed so that either may be isolated in the event of an epidemic. Also separate are stables for the 40 horses used in the production of immunizing serums, the manufacture of which is an important feature of the work of the laboratories.

The animal houses accommodate annually about 5,000 guinea-pigs, between 500 and 1,000 rabbits, 50 to 100 monkeys, 3,000 to 5,000 white mice and 30 calves. Most of these are bred locally for use in the laboratory work, though the strain is supplemented each year by pure blood stock, rabbits being imported from Hampstead, England. In connection with the stables is a model horse hospital, complete with a huge operating table to which the animal is tied in a standing position, then tilted back so that he lies in front of the veterinarian in the desired position.

MODERN LABORATORY FACILITIES

AN INTERIOR VIEW OF ONE OF THE LABORATORIES IN THE MAIN BUILDING OF THE MICHIGAN STATE DIAGNOSTIC RESEARCH CONTROL LABORATORY. PERCY O'MEARA, OF THE CHEMISTRY SECTION OF THE MICHIGAN DEPARTMENT OF AGRICULTURE, IS SHOWN EXAMINING THE OPERATION OF A CRUDE FIBER APPARATUS USED FOR STOCK FEED ANALYSIS.

THE NORTH POLE DRIFTING STATION

SAFE removal of the four Soviet scientists from the ice east of Greenland on February 19 brought to a close one of the most unique voyages in history. Deposited by airplanes on an ice-floe $12\frac{1}{2}$ miles from the North Pole on May 21, 1937, the scientists were picked up from a remnant of the same ice-floe 274 days later, 1,324 miles from the North Pole. Though deeply stirring as a spectacular and dramatic adventure, the real importance of this undertaking lies in its scientific revelations and its significant role in the Soviet Union's efforts to study and develop its portion of the Arctic in a thoroughly scientific, practical and systematic way.

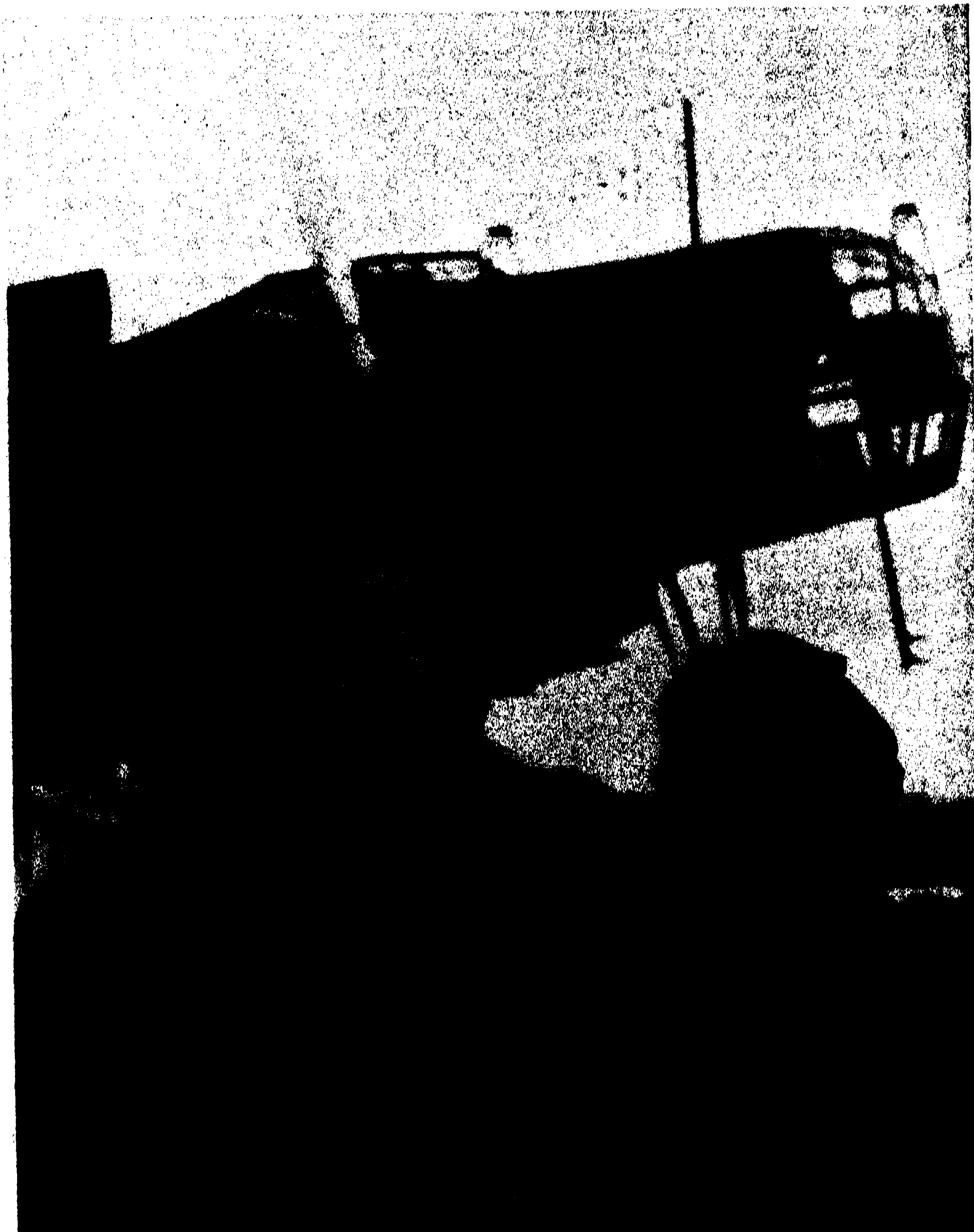
In 1936 there were over 50 scientific stations on the islands and mainland of the Soviet Arctic, a network forming a vast semicircle around the central part of the Arctic Sea. None of these stations, however, was within 600 miles of the North Pole. It was to fill this vacancy, to conduct scientific studies in the central Arctic, to report the weather conditions near the Pole, and to provide a base for trans-Polar flights that the station, known as Station 56, was established on the ice near the Pole.

Final preparations for the expedition were begun in the fall of 1936, when a station and air base were established on Rudolf Island at the northern end of Franz Josef Land, 560 miles from the Pole. During the early spring of 1937 planes, specially equipped, flew to Rudolf Island. On May 5, under the command of Professor Schmidt, chief of all the Soviet Union's Arctic operations, a reconnaissance flight was made over the Pole and it was ascertained that heavily loaded planes could land in that area. On May 21, one plane with Professor Schmidt in command landed $12\frac{1}{2}$ miles from the Pole and established the station on an ice-floe which was over a square mile in area and had an average thickness of about nine feet. Three other planes arrived at the station between May 26 and June 6 with all the necessary supplies for a full year's work. For a few

—*Sovfoto*

A CATERPILLAR TRACTOR ON RUDOLF ISLAND

HAULING ONE OF THE PLANES OF THE EXPEDITION TO THE STARTING POINT BEFORE TAKING OFF TO THE NORTH POLE.



—Sovfoto

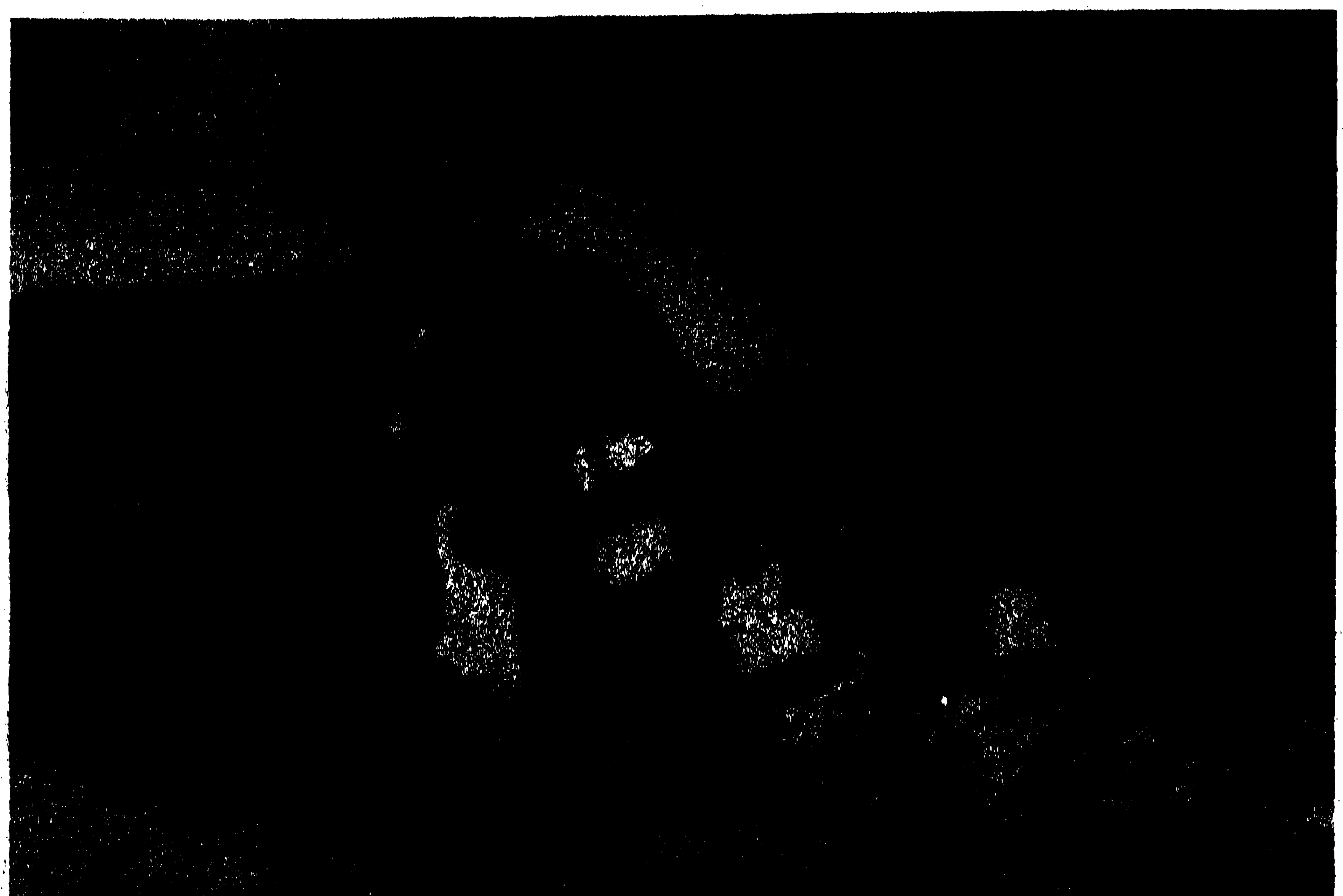
DR. O. J. SCHMIDT, HEAD OF THE NORTH POLE EXPEDITION
WITH HIS SON AT THE MOSCOW AIRDROME BEFORE THE TAKE-OFF OF THE EXPEDITION.

hours on June 6 there were 35 men at the station. Then the four planes returned, leaving the scientific work in charge of four men. Besides the leader, Ivan Papanin, the staff consisted of the astronomer, Eugene Federov, the marine biologist and hydrologist, Peter Shirshov, the radio operator, Ernst Drenkel, and Jolly, the dog.

The scientific work of the station began on May 21 and communication was set up with the network of Soviet Arctic stations and other parts of the world. Weather reports were sent out on a schedule of four times per day, except during the trans-polar flights, when reports were made every three hours. The meteorological data thus provided has ! been of the utmost value to students of world weather conditions and to weather forecasting in Europe, Siberia, Canada, Alaska and the United States. It has revealed that weather in the polar regions is subject to more change than was previously believed and that storms from the North Atlantic penetrate to the Pole itself.

Throughout the drift, the station made careful studies of ice conditions, the waters and currents at various depths, and submarine topography, the sea floor, marine life, the force of gravity, terrestrial magnetism, radio transmission and various phenomena of special interest to students of the Arctic. Thus, an enormous amount of information has been assembled about one of the most inaccessible and least known regions of the earth, which had never before been visited. The conditions for work were extremely difficult and were made more so by rain and excessive melting in the summer, frequent storms and total darkness for over three months. However, throughout the nine months the schedule of the scientific work was maintained. The station also had a definite share in the success of the first two trans-polar flights, as it had previously been decided that no attempts should be made until a base could be established near the Pole for weather reports and for emergency landing purposes.

The extent to which radio communica-



—Sovfoto

TENT OF THE SOVIET EXPEDITION

BEING PACKED WITH ICE BY I. PAPANIN, CHIEF OF THE WINTERING PARTY.

tion was used proved one of the truly remarkable aspects of the expedition. When the windmill generated enough electricity for continuous operation, a constant stream of messages was transmitted and received. For instance, on January 1 a total of 6,754 words was sent out. Accounts of the daily happenings were dispatched all over the world, presenting the humorous incidents as well as the observations and the problems and dangers of the work. The men talked with their families thousands of miles away and listened to radio broadcasts of all descriptions.

It had not been expected that the ice-floe would remain in one place, since the existence of the great Arctic current was known before the station was established. However, it was not known exactly how currents and winds affect the ice near the Pole. For although Nansen's ship, the *Fram,* had drifted from 1893 to 1896 across the Arctic Sea, it had not approached nearer than 280 miles from the Pole. From the moment the station was established in May, 1937, though the drift was in zigzags, the unmistakable trend was in direction of the North Atlantic. At first the southward progress was slow and occasionally was reversed, but in the seventh month it began to be more rapid, until in the last month the camp was moving southward at the rate of 25 miles per day. The detailed observations made during this drift shed light not only on this vast current itself but also on the general circulation of the waters of the Arctic Sea and the influence of the great northward-flowing counter-current, the Gulf Stream.

The emergency rescue of the party from the ice was necessitated by the increasingly rapid drift to the south. It had been thought possible that the station might continue to operate for a year or more and that physical contact with it might not be necessary until the spring of 1938. Late in 1937, however, as the station drifted near the coast of Greenland, it was realized that an emergency might occur earlier than expected, due to the rapidly converging currents and severe polar storms which were endangering the stability of the ice-floe. On February 1, the floe suddenly began to split up and by the next day it was reduced in size to about 150 by 210 feet. Rescue operations were then hastened.

As in the rescue of the Cheliuskin expedition in 1934, air and sea forces were being mobilized in the meantime for coordinated action. In January the small hydrographic vessel, *Murmanets,* had sailed for the Greenland Sea to conduct observations of weather and ice conditions. On February 3 and 7 two small ice-breakers, the *Taimyr* and *Murman,* sailed, followed on the ninth by the USSR's second largest icebreaker, the *Yermak,* all equipped with planes. Several large planes equipped for possible long over-sea flights to the ice-floe were being prepared, and the Soviet Union's largest dirigible was on a test flight to participate in the rescue when it crashed. At the same time land parties, under Norwegian and Danish direction, began work on the east coast of Greenland.

After encountering severe winter gales, the *Taimyr* reached a point 20 miles from the polar station on February 13 and the *Murman,* penetrating the ice from another direction, came in sight of the station two days later. On February 16, after several attempts, a plane from one of the icebreakers landed at the station, establishing the first physical contact since June 6. Finally on February 19 the *Taimyr* and *Murman* reached a point near the station and took aboard the four scientists and their dog, as well as all the scientific records and equipment.

The establishment of more such drifting stations may follow as a result of the success of this expedition in contributing to the program of study and conquest of the Soviet Arctic. Already Soviet scientists have discussed plans for studying the area "on the far side of the Pole"—that is, in the North American sector, which now remains the least known part of the Arctic.

American Russian Institute

THE SCIENTIFIC MONTHLY

MAY, 1938

CURRENT MILKY WAY PROBLEMS

By Dr. BART J. BOK
HARVARD COLLEGE OBSERVATORY

THE study of the universe of galaxies has in recent years received so much attention from the writers of popular science that the interested layman might well have formed the opinion that the golden days for work on our own milky way system are over. This is most certainly not so. The available evidence on the general shape and outline of the milky way system appears to be more or less conclusive, and it seems unlikely that our views on these points will undergo radical changes in the near future. At present very little is known, however, about the details of milky way structure. We shall describe briefly in the first section the facts on which our present information on the location of our sun in the milky way system is based, and discuss in subsequent sections our present state of knowledge concerning the motions and distribution of the stars in our system.

1. THE OUTLINE OF THE MILKY WAY SYSTEM

The band of the milky way, which forms one of the finest features of the summer skies in our latitudes, plays a fundamental rôle in all studies of the structure of the particular stellar system to which our sun happens to belong. This milky way system (or, as it is frequently called, our galactic system) comprises all stars visible to the naked eye, and a great majority of the telescopic stars. Not unlike the spiral galaxies, which are observed in great abundance with modern reflectors, our galactic system is highly flattened. Its shape follows roughly the outline of the flattened ellipsoid of revolution shown in the accompanying diagram, in which the location of the sun has been indicated by a cross. Modern observations place the sun at a distance of thirty to thirty-five thousand light years from the galactic center, at a point that is at the most one hundred and fifty light years above the galactic plane. The scale of the diagram does not permit us to indicate the northerly position of the sun and for most practical purposes the sun may be considered as located in the plane of symmetry. What is, briefly, the observational evidence that has led astronomers to agree generally that the shape of our milky way system is approximately as shown in the diagram?

First, let us consider the high degree of flattening of the system. Observations have shown that there exists a considerable range in the average distances of the stars which together give us that magnificent impression called "the milky way." This by itself eliminates immediately the possibility that the milky way as viewed from the sun or earth (their positions are the same, galactically speaking) could be caused by a single starry ring of limited depth, a hypothesis which naturally suggests itself to the untutored

observer. The band-like appearance of our milky way is caused by the high degree of flattening of our galactic system.

Second, how do we know that the sun has an eccentric position in the system? If the sun were anywhere near the galactic center we would expect fairly constant brightness all around the milky way. It is true that some separate star clouds or dark nebulae might cause occasional fluctuations in brightness, but there would be no reason to expect any large-scale variations. We do, however, observe such variations. The half of the milky way from Cygnus through Sagittarius to Carina is very much more brilliant than the other half, which passes through the constellation of Orion. The

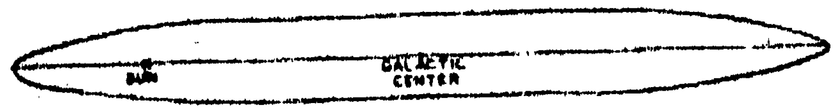


FIG. 1. THE APPROXIMATE SHAPE OF OUR MILKY WAY SYSTEM.

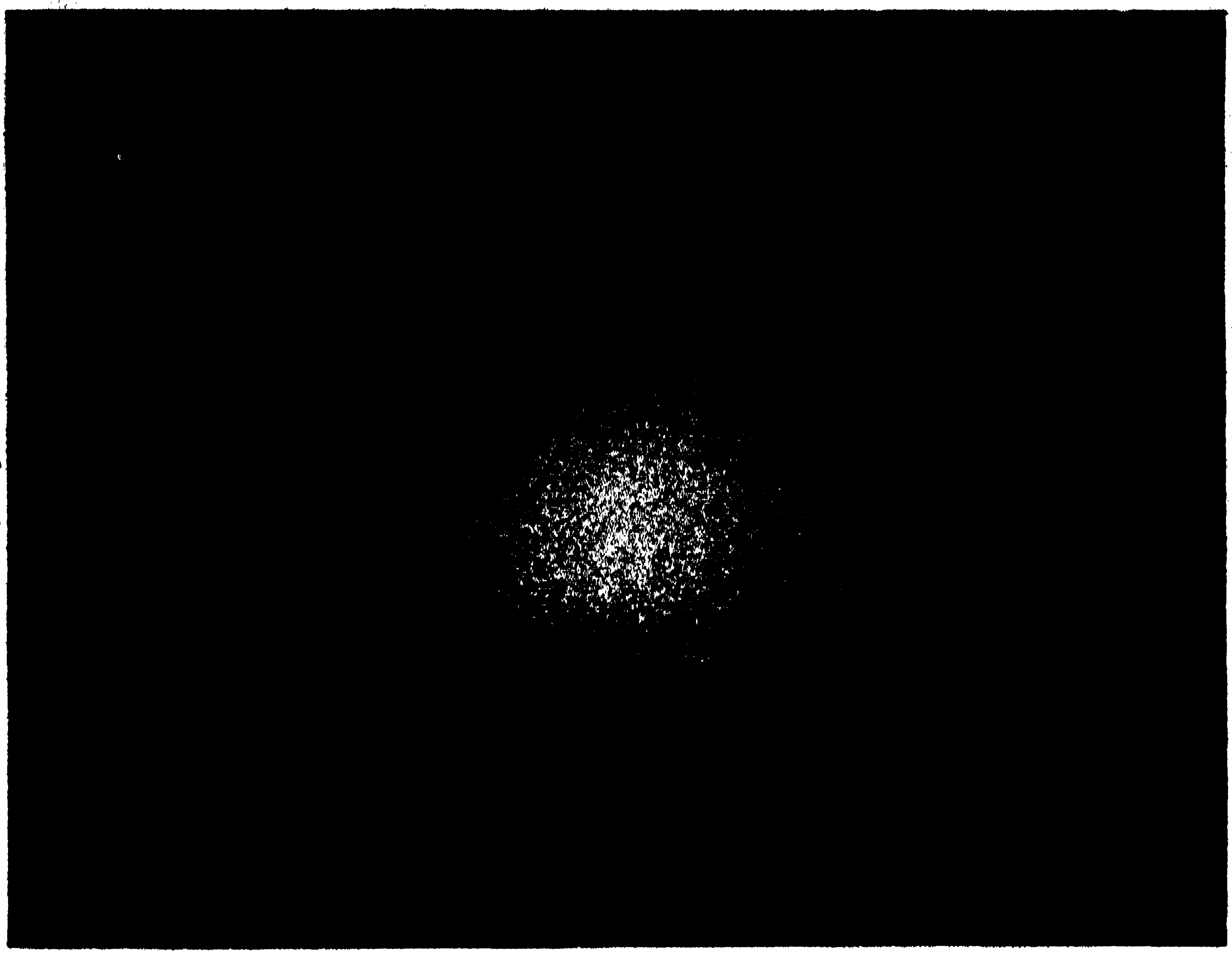
central portion of the milky way falls clearly in the direction of the constellation of Sagittarius, and it is there that we look at present for the center of the galactic system.

There are several independent lines of evidence which support the hypothesis of the distant center in Sagittarius. The globular star clusters are conspicuously concentrated toward the Sagittarius region, to which Charlier referred as the "home" of the globular clusters. Shapley's work has shown that the globular clusters are among the most distant observable galactic objects, and their concentration toward one hemisphere of the sky suggests that our sun is nowhere near the center of the galactic system. The globular clusters are by no means the only objects that show a decided preference for the milky way regions around Sagittarius. The same phenomenon is exhibited by almost every type of object that can be observed at large distances from the sun. New stars or novae, faint distant variable stars, planetary nebulae, all show a similar concentration.

Further corroborative evidence has been contributed by the theory of galactic rotation. Our galactic system is highly flattened, and this alone is strongly suggestive of rotation of the system as a whole. Oort and Lindblad showed that the existence of such a rotation could be demonstrated from studies on the distribution of the motions of the stars and incidentally proved from their results that the direction toward the center of rotation is somewhere in Sagittarius.

The location of our sun with respect to the center of the galactic system has for many centuries been a point on which the astronomer had no definite information. This has all been changed during the past twenty-five years, and it appears to be highly improbable that the sun will ever be restored to the central position in our galactic system, which it was once supposed to occupy.

There finally remains the matter of the scale of our schematic diagram. Shapley's original investigation suggested a value of well over fifty thousand light years for the distance of the sun from the galactic center, while the first computation from the theory of galactic rotation by Oort gave twenty thousand light years for the same distance. Investigations made since 1929–30 by Trumpler and many others have shown that considerable interstellar absorption is present and that the light from distant objects is dimmed correspondingly. Shapley's original distances of globular clusters should therefore be reduced by approximately thirty per cent. More recent observational material bearing on the theory of galactic rotation (in particular, the radial velocities contributed by Plaskett and his collaborators and by Joy) has shown that Oort's original estimate for the distance of the sun from the galactic center had to be increased. Astronomers are now pretty well agreed that the galactic



THE GLOBULAR CLUSTER ω CENTAURI

FROM A PHOTOGRAPH TAKEN BY DR. J. S. PARASKEVOPOULOS WITH THE 60-INCH REFLECTOR OF THE BOYDEN STATION OF THE HARVARD OBSERVATORY AT BLOEMFONTEIN, SOUTH AFRICA.

center lies somewhere between thirty and thirty-five thousand light years from our sun. It is impossible to say just where is the outer boundary of our galactic system: the full-drawn line in our diagram is drawn through points where the space density of the stars could hardly exceed a few per cent. of the value near the sun.

It is only natural that the reader will ask further information about some of the details not shown in the schematic diagram. Is our galactic system a spiral nebula? Do separate star clouds exist in the system? What is known about the interstellar medium, which apparently plays an important part in studies of galactic structures? Unfortunately, it is impossible to give straightforward answers to these questions now. We can, however, discuss the problems that currently have the attention of the galactic investigators, and show in this fashion not only what progress has already been made, but also where further research is most urgently needed.

There is a broad division into two groups of problems, the first of which includes investigations dealing with galactic structure, whereas the questions relating to stellar motions and the dynamical properties of the system form a second division. The appearance of the milky way is influenced to a considerable extent by the presence of absorbing material which either partly or totally hides distant galactic objects from our view. We shall therefore precede the discussion of the problems of galactic structure and stellar motions with a brief survey of our knowledge of the interstellar medium.

THE REGION OF THE GREAT STAR CLOUD IN SAGITTARIUS

FROM A PHOTOGRAPH TAKEN WITH A 1½-INCH COOKE LENS. MORE THAN ONE QUARTER OF ALL KNOWN GLOBULAR CLUSTERS FALL WITHIN THE LIMITS OF THE REGION SHOWN ON THIS PLATE, WHICH COVERS AN AREA OF ONLY TWO PER CENT. OF THE ENTIRE SKY.

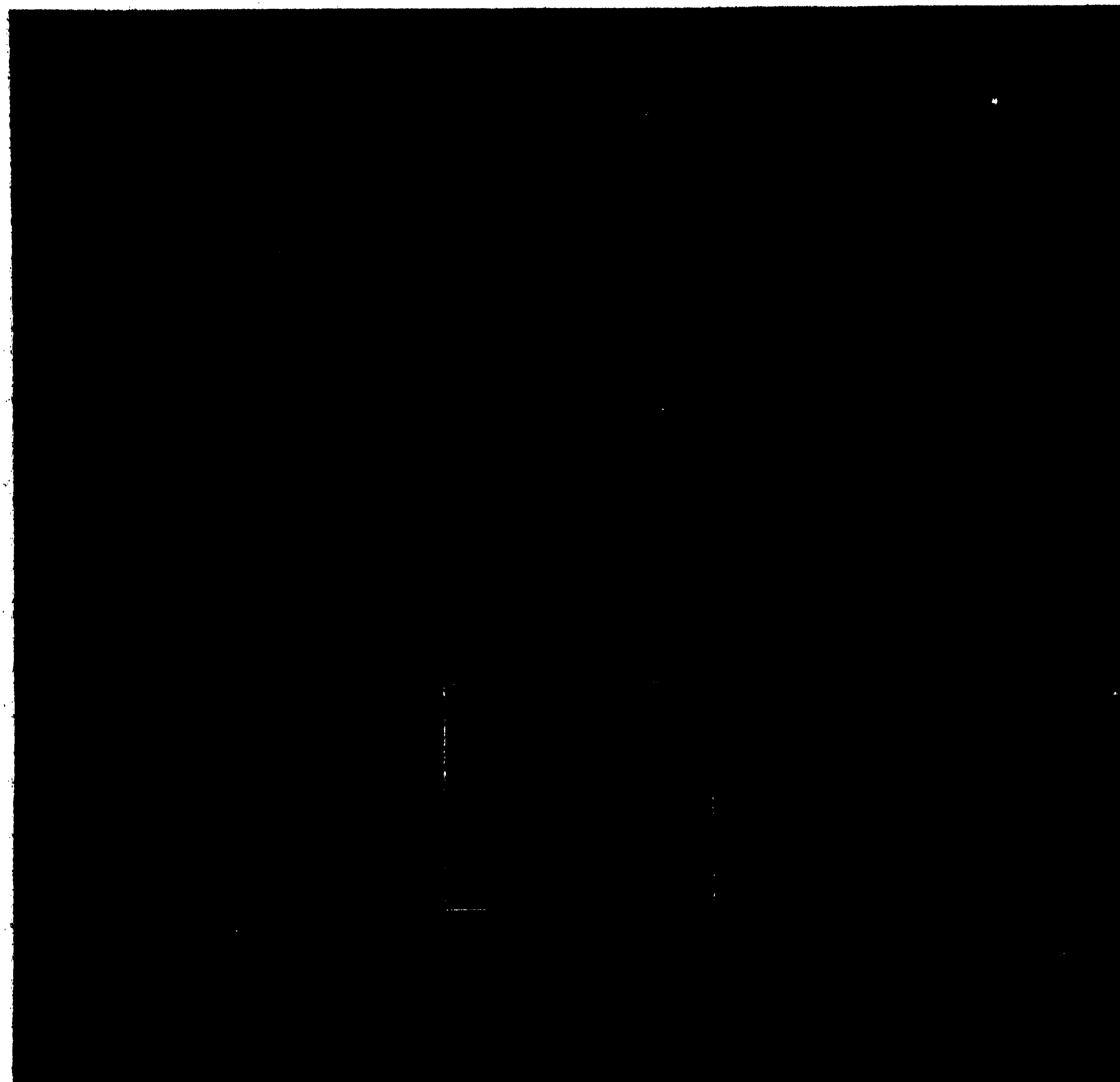
2. The Interstellar Medium

The particles which inhabit the regions between the stars vary all the way from tiny electrons and atoms to meteoric particles of the size of an average pin-head. The blocking of the light of distant galactic objects is caused neither by single atoms or electrons nor by meteoric particles, but it has been shown that particles with dimensions of the order of one tenth to ten times the wave-length of visible light are chiefly responsible. If a dense cloud of large meteoric particles were between the earth and a distant star, the star would appear fainter because of the resultant absorption, but no change in color would be observed. If the same cloud were to consist of particles with dimensions small compared to the wave-length of visible light not only would the star appear fainter, but its light would become distinctly reddened. Every one is familiar with the last type of scattering of light; the small particles in the earth's atmosphere scatter the blue waves in the light of the sun more effectively than the red ones, an effect which for example, causes the setting sun to be red and the sky to be blue. The degree of reddening accompanying a given total amount of absorption for photographic light is a measure for the particle sizes of the most effective absorbers.

There are several types of luminous stars for which the intrinsic colors can be predicted from spectral studies. The measured colors of such objects will yield information on the change in color caused by the passage of the light through the interstellar medium, and give definite clues for the derivation of the distribution of particle sizes. Valuable contributions have been made by Stebbins, Trumpler, Struve, Schalén and many others, and the presence of a slight amount of space reddening has been established. It is from the observational studies of colors of distant stars that our knowlege of the average particle sizes has been derived.

The galactic investigator is primarily interested in the effect of the interstellar absorption on the appearance of the milky way and hence wishes to know what corrections for interstellar absorption should be applied in the analysis of data on stellar distribution. We turn therefore now to those investigations which have led to a determination of the total amount of dimming of star light in the photographic region of the spectrum for various directions in the milky way. If we know both the amount of the change in color and the law of variation of absorption with wave-length, it becomes a simple matter to compute the total absorption of photographic light. More direct methods for the derivation of the total photographic absorption should, however, be preferred as long as we have only meager information on the law of variation of extinction for separate wave-lengths.

In the original investigation, which led to the general acceptance of the presence of a considerable general absorption of light near the galactic plane, Trumpler made use of measurements of diameters for galactic star clusters. Such diameter estimates are unfortunately rather arbitrary, but in spite of the difficulties involved Trumpler's original value for the coefficient of interstellar absorption has stood up remarkably well. The most dependable value for the average coefficient of absorption can now be obtained from the galactic rotation effects in the radial velocities of distant stars and nebulae (Joy, Berman); it is found that the coefficient of absorption for photographic light amounts to one quarter of a stellar magnitude for a distance of one thousand light years. The analysis of the available data on star counts shows that it is extremely unlikely that the value of the coefficient will exceed three tenths of a



THE REGION OF THE SOUTHERN GALACTIC WINDOW

WITHIN 25° OF THE GALACTIC CENTER, DISCOVERED BY SHAPLEY IN THE COURSE OF THE HARVARD SURVEY OF FAINT EXTERNAL GALAXIES. THE WHITE LINES MARK THE PARTICULAR AREA IN WHICH MANY FAINT EXTERNAL GALAXIES HAVE BEEN FOUND. A STRIKING FEATURE OF THE PHOTOGRAPH IS THE LACK OF ANY VISIBLE EVIDENCE FOR DIFFERENCES IN THE STELLAR DISTRIBUTION BETWEEN REGIONS IN AND AROUND THE WINDOW, WHICH IS CONFIRMED BY ACCURATE STAR COUNTS. THE MOST PROBABLE CONCLUSION IS THAT THE INTERSTELLAR ABSORPTION IN THE PARTLY OBSCURED REGIONS ON EITHER SIDE OF THE WINDOW IS NOT VERY LARGE.

magnitude. The average coefficient holds for regions close to the galactic plane, and it can be shown from the distribution of stars and nebulae away from the plane that the effective thickness of the galactic absorbing layer is certainly not in excess of two thousand light years.

At present we are, however, no longer so very much concerned with the average coefficient of absorption, but the attention is gradually being focused upon the variations in the amounts of interstellar absorption from one region to the next. A glance at any milky way photograph will convince the reader better of the importance of fluctuations in the interstellar absorption than could a long preamble. The characteristic feature of all milky way photographs is that of marked irregularities in stellar distribution.

Dark lanes and regions of star-deficiency are present on all such photographs and one of the main problems of to-day is to decide what fraction of the general interstellar absorption arises in isolated dark nebulae. Around 1930 most astronomers were of the opinion that a smooth continuous medium was probably responsible for the interstellar absorption. This has gradually changed, and there is now a considerable following for the hypothesis that isolated dark nebulae may account for at least 50 per cent. of the total interstellar absorption. Several reasons have led to this change of opinion.

It was only natural, at the time that the suggestion of general interstellar absorption was first put forward, to assume a more or less uniform distribution of the interstellar medium and obtain in this way at least some information about its most general properties. It might have been expected that more refined studies would lead to modifications in the first crude hypothesis. Astronomers have during the past ten years paid considerable attention to the study of isolated dark nebulae. The survey has not been finished by any means, but already we can see that the known nebulae alone contribute significantly to the general absorption. Some of the isolated dark nebulae cover tremendous areas of the sky; the dark nebulae in Ophiuchus and Scorpio cover an area of one thousand square degrees of the sky, which is equivalent to five thousand times the area covered by the full moon. The light of the stars beyond these tremendous dark nebulae is dimmed by at least a full magnitude.

Further evidence for the importance of condensations in the interstellar medium has come from studies of the distribution over the sky of distant external galaxies. There are literally millions of such objects within the reach of modern telescopes. Each galaxy that is found on one of our photographs (there are sometimes more than a thousand on one single plate!) is again a stellar system not unlike our own galactic system. These external galaxies are extremely numerous away from the galactic plane, but it has long been known that their frequency decreases as we approach the band of the milky way. Our own milky way system is only one of many and it would be downright silly to suppose that our particular galactic plane would be a plane of symmetry in the universe of galaxies. The lack of external galaxies near the band of the milky way is caused by our galactic interstellar medium, which simply screens off the light of distant external galaxies. The absence of the galaxies near the band of the milky way gives therefore proof for the existence of an interstellar absorbing medium.

This is all an old story, but in recent years the studies of the distribution of faint external galaxies at Mount Wilson and at Harvard have given further information about the interstellar medium which has led to the discovery of what Shapley calls so aptly "galactic windows." A galactic window is a region close to the band of the milky way, where rather unexpectedly external galaxies pop up in great numbers. The fact that we see these nebulae is by itself evidence that, in that particular direction, the density of the absorbing medium should be very small. In a few regions near the galactic circle we observe many such galaxies, while in neighboring fields we do not find a single one. This is all very puzzling, if we assume that there exists a smooth, continuous interstellar medium, but the discovery of galactic windows can be interpreted as that of "the holes in between the clouds," if the absorbing medium is supposed to be composed of isolated dark nebulae.

Obviously one of the most important future problems is to make a complete survey of the distribution of faint external galaxies within twenty degrees of the

galactic circle. This, together with the survey of the distribution of isolated dark nebulae, should go far toward unraveling the remaining mysteries of the absorbing interstellar medium.

3. Structural Problems

It is necessary to have full information on the properties of the absorbing medium before we can tackle with any hope of success the problems of the distribution of the stars in space. Our present data on interstellar absorption are unfortunately far from complete, and it is very much easier to write down a list of topics that await further study than it would be to make some positive remarks about the distribution of the stars at various points in the galactic plane.

If we know for a given direction the amount of absorption at various distances from the sun, it is possible to find the run of the star densities for that direction from the analysis of star counts, or from studies on the distribution of spectral types and colors. Because of the fluctuations in star density and absorption from one region to the next, we can not expect to obtain significant results from analyses of distributions which represent averages for many galactic fields. It is safe to predict that our knowledge of galactic structure will be advanced most rapidly by detailed investigations of regions of limited extent.

The equipments of several of the larger American observatories are excellently suited for investigations of this type. Star counts for large fields can be obtained to the fifteenth magnitude with a four-inch photographic camera; and while it would be too time-consuming to count all stars to the nineteenth or twentieth magnitude, it is a simple matter to obtain counts for a few sample regions with a larger reflector or refractor. Spectral types can be obtained for all stars to the twelfth magnitude, and, with a little extra effort, it is quite possible to extend the survey for some small regions to the fourteenth magnitude. Color observations for the same stars present no difficulty; and since it is possible to deduce true colors and approximate absolute magnitudes from the spectral types, a comparison between the true and observed colors will yield directly information on the reddening caused by interstellar absorption for the field under investigation. The star counts give further data on the distribution of isolated dark nebulae, and by adding surveys for the distribution of faint external galaxies, the absorption properties of the field become known. It is then a straightforward process to derive the density distribution for the stars at large from star counts and, from the spectral survey, for each spectral type separately.

Studies of proper motions and radial velocities, as well as investigations of the distribution of variable stars, have not been included in the above program, but would be a considerable help for the final analysis. The proper motions would make possible the separation of giants and dwarfs among the cool stars, the nearby dwarfs showing on the average much larger angular displacements than the distant giants. The proper motions might also help further in the absorption analysis, but recent work along this line has not been too encouraging. Radial velocities of faint stars can be determined in great numbers with the objective prism method that has recently been developed as a working tool at Harvard. These velocities provide a check on the absorption properties of the field if the galactic-rotation term happens to be large enough. They will be of importance for a further dynamical interpretation of the observed density distribution. Studies of the distribution of variable stars would finally aid particularly in investigations of limited regions of high star density.

THE SOUTHERN MILKY WAY FROM CARINA TO CENTAURUS

THE CONSPICUOUS DARK NEBULA CALLED THE "COAL SACK" CAN BE SEEN NEAR THE CENTER OF THE PHOTOGRAPH. TO THE RIGHT AND SLIGHTLY ABOVE THE COAL SACK-NEBULA ONE IDENTIFIES THE SOUTHERN CROSS WHICH, BECAUSE OF THE REDNESS OF TWO OF ITS MEMBERS, IS NOT SO CONSPICUOUS ON PHOTOGRAPHS AS TO THE NAKED EYE. THE BRIGHT STAR IN THE BAND OF THE MILKY WAY NEAR THE LEFT EDGE OF THE PHOTOGRAPH IS α CENTAURI, ONE OF THE NEAREST NEIGHBORS OF OUR SUN. THE DIFFUSE NEBULA NEAR η CARINAE (SEE NEXT PLATE) IS SHOWN AS A FUZZY OBJECT CLOSE TO THE RIGHT EDGE OF THE PHOTOGRAPH.

I could go on and enter into more details, but I hope to have succeeded in demonstrating that modern astronomical technique enables us to attack successfully the problem of the density distribution for a region of limited size. What regions will it be well to pay particular attention to? First on the list come undoubtedly the galactic windows, in which the absorption bugaboo does not bother us at all; second, the regions near the galactic plane apparently not affected by isolated dark nebulae; and third, regions within fifteen degrees of the galactic circle which are free from the influence of obscuration.

It was shown earlier in the present article that we are reasonably well informed on the general outlines of our galactic system, but that our knowledge of the structural details is practically nil. The best we can do is to indicate the types of problems in galactic structure that may be considered as more data are gradually becoming available.

1. The local system: It has long been known that, if we disregard the presence of interstellar absorption, the observed run of star counts to the twelfth magnitude indicates a rapid decrease in the star density with increasing distance from the sun for every direction in the galactic plane. The first thought of many astronomers after the discovery of interstellar absorption must have been that now there was an opportunity to get rid of those negative density gradients, which indicated formerly a rather peculiar position of the sun in the galactic system. Subsequent investigations, based largely on star counts assembled by Kapteyn, van Rhijn and Seares, did not confirm this guess. There remained unmistakable indications that the sun is near a region of high star density and that the density drops rapidly in some directions away from the sun, particularly in the directions toward, and diametrically opposite from, the galactic center. No very pronounced drops are, however, found along a line passing through the sun in a direction perpendicular to that to the galactic center; the star densities appear to be reasonably constant over a distance of at least five thousand light years in a direction toward the constellations of Cygnus and Carina. Does this observation indicate that our sun is part of a finite local system elongated along the line Cygnus-Carina, *i.e.*, in a direction perpendicular to that of the galactic center? This is an attractive hypothesis, and the picture of local system elongated because of the rapid whirls in our rotating galaxy has considerable appeal. We have, however, no information whatever as to what happens beyond five thousand light years, and it is not at all impossible that our local system is only a small part of a giant spiral arm passing through our sun.

The first job will be to study more carefully the density distribution for various directions in the galactic plane. Data on the individual parallaxes, proper motions and radial velocities are accumulating rapidly for the brighter stars; at the same time large amounts of material on colors, the distribution of spectral types and general star counts are becoming available for the fainter stars. Before long it should be possible to establish or disprove beyond reasonable doubt the reality of the local system.

2. Star clouds: The irregular appearance of the milky way has led to the designation of certain regions of high star density as the Cygnus cloud, the Scutum cloud, etc. Is our milky way perhaps an aggregate of star clouds? The hypothesis of galactic rotation does not favor such a hypothesis, since it can be shown that most star clouds would be disrupted within a few galactic revolutions by the tidal forces of the galactic nucleus. But then, the theory of galactic rotation may be partly wrong and the matter of the reality of star clouds should be decided on the basis of the data on stellar dis-

tribution and not by some roundabout theoretical argument.

The suspected star clouds are without exception at such large distances from the sun that it will take highly effective use of the world's largest telescopes to obtain data for the crucial test as to the reality of these clouds. We know already that the apparent boundaries of several star clouds are caused in part by the presence of near-by dark nebulae, which simply screen off the light of remote stars in certain directions. Few star clouds have as yet been investigated completely, but a recent analysis of the stellar distribution in the constellation of Cygnus by Miller shows that the Cygnus cloud will probably have to be removed from the list of the real star clouds. While some giant star clouds are in danger of being disqualified as such, there will undoubtedly remain a good many smaller condensations of which the reality can not be denied. Particularly some of the highly luminous stars appear to prefer to come in bunches and it seems almost certain that these condensations are real.

The types of observations that should be made in order that the controversy about the star clouds may be settled are very much the same as those suggested for the study of the local system. Only —the magnitude limits for the various surveys should be at least two magnitudes fainter than those set for the local system surveys.

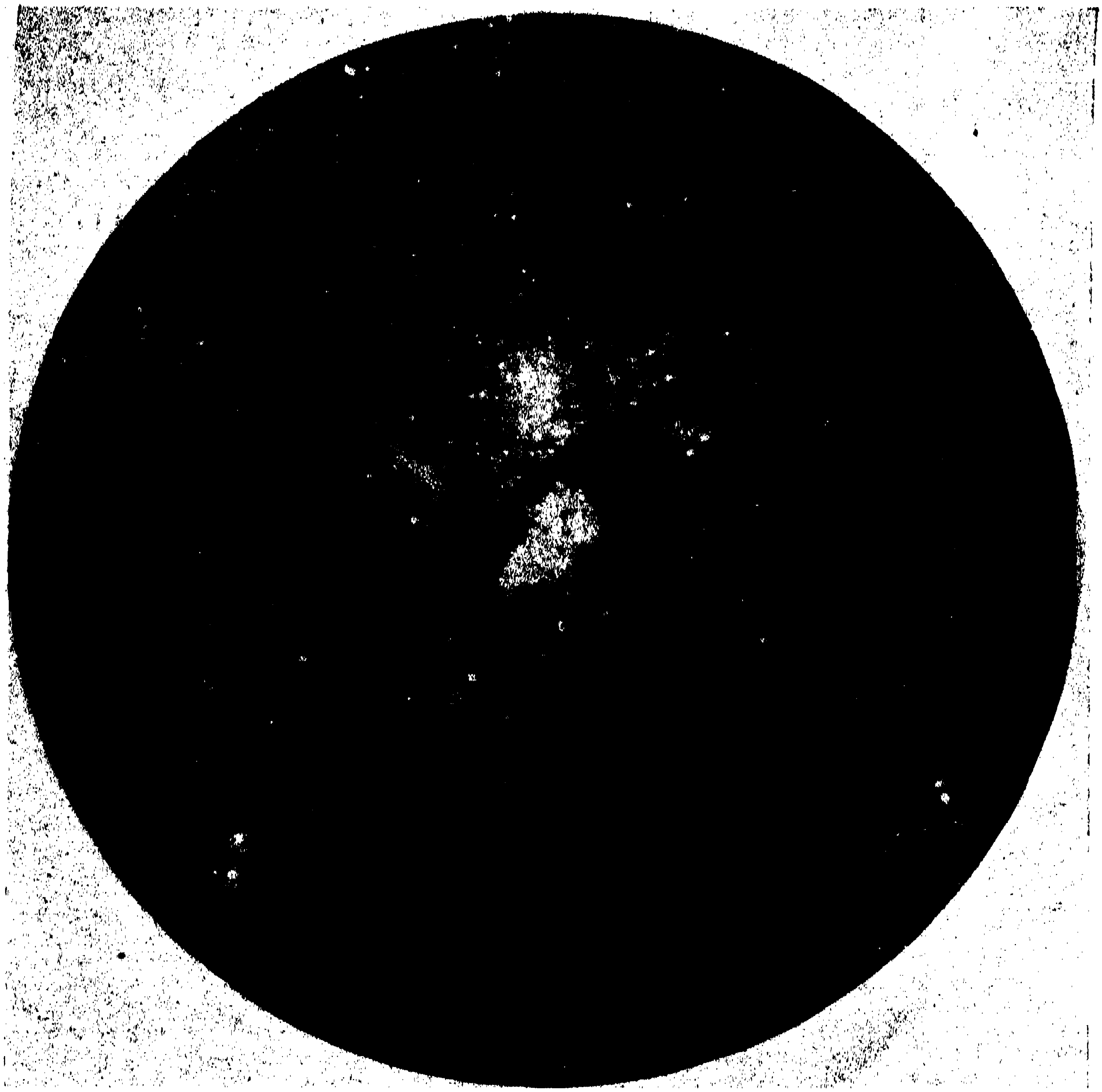
3. The galactic nucleus: Shapley's work on the globular clusters and the Oort-Lindblad theory of galactic rotation suggest the presence of a massive galactic nucleus at a distance of thirty to thirty-five thousand light years from the sun in the direction toward Sagittarius. The great star cloud in Sagittarius has commonly been identified as the galactic nucleus. There is little doubt but that the center of our milky way system is located in a direction which differs by not more than ten degrees from that toward the Sagittarius cloud, but several considerations indicate that we may not have yet observed the real galactic nucleus at all.

Star counts and studies of the distribution of spectral types suggest that a drop in the star density in the direction of the Sagittarius cloud stops at a distance of the order of two to three thousand light years and is followed by a steep rise, which sets in at approximately five thousand light years from the sun. Beyond this there comes, in all probability, a region of continued high density. This observation suggests that the main body of the great star cloud of Sagittarius is considerably closer to us than the galactic center.

The original evidence for the Sagittarius cloud's being the galatic nucleus was based upon observations of variable stars. Unfortunately there is not much information available on the distribution of absorbing matter for that particular region of the sky, and the analysis of the available data is correspondingly difficult. The study of the distribution of spectral types in the Sagittarius cloud has been undertaken by Wallenquist, but it is to be hoped that his work will be supplemented by investigations with some of the largest reflectors.

The galactic nucleus should not necessarily be an approximately spherical star cloud with a radius of the order of two to four thousand light years. Lindblad has shown, from dynamical considerations, that it is very likely that the nucleus of a rotating galaxy would become highly flattened. In fact, it might be so flattened that its outer edge might come to within ten thousand light years of the sun. All the more reason to attempt detailed studies of this part of the sky with large reflectors.

Even if it were so that absorbing matter would shield the galactic nucleus forever from our view, there are still two ways open for ascertaining the mass and



THE DIFFUSE NEBULA NEAR THE STAR η CARINAE
A PHOTOGRAPH TAKEN SEVERAL YEARS AGO WITH THE 13-INCH BOYDEN REFRACTOR AT AREQUIPA, PERU.

dimensions of this nucleus. Studies of the radial velocities of distant objects like faint variable stars (Joy) or planetary nebulae (Berman) have already shown that much information on the distribution of matter in our galactic system can be obtained from the variations in the average radial velocities of certain groups of distant stars and nebulae. A second way has been suggested by Oort in connection with the distribution of stellar velocities perpendicular to the galactic plane for objects at large distances above or below the plane. These velocities are to a great extent governed by the gravitational pull exerted by the galactic nucleus. It is indeed not impossible that careful studies of objects in the star-empty regions around the galactic pole may give the most reliable information on the nucleus of our milky-way system.

4. Stellar Motions and Galactic Dynamics

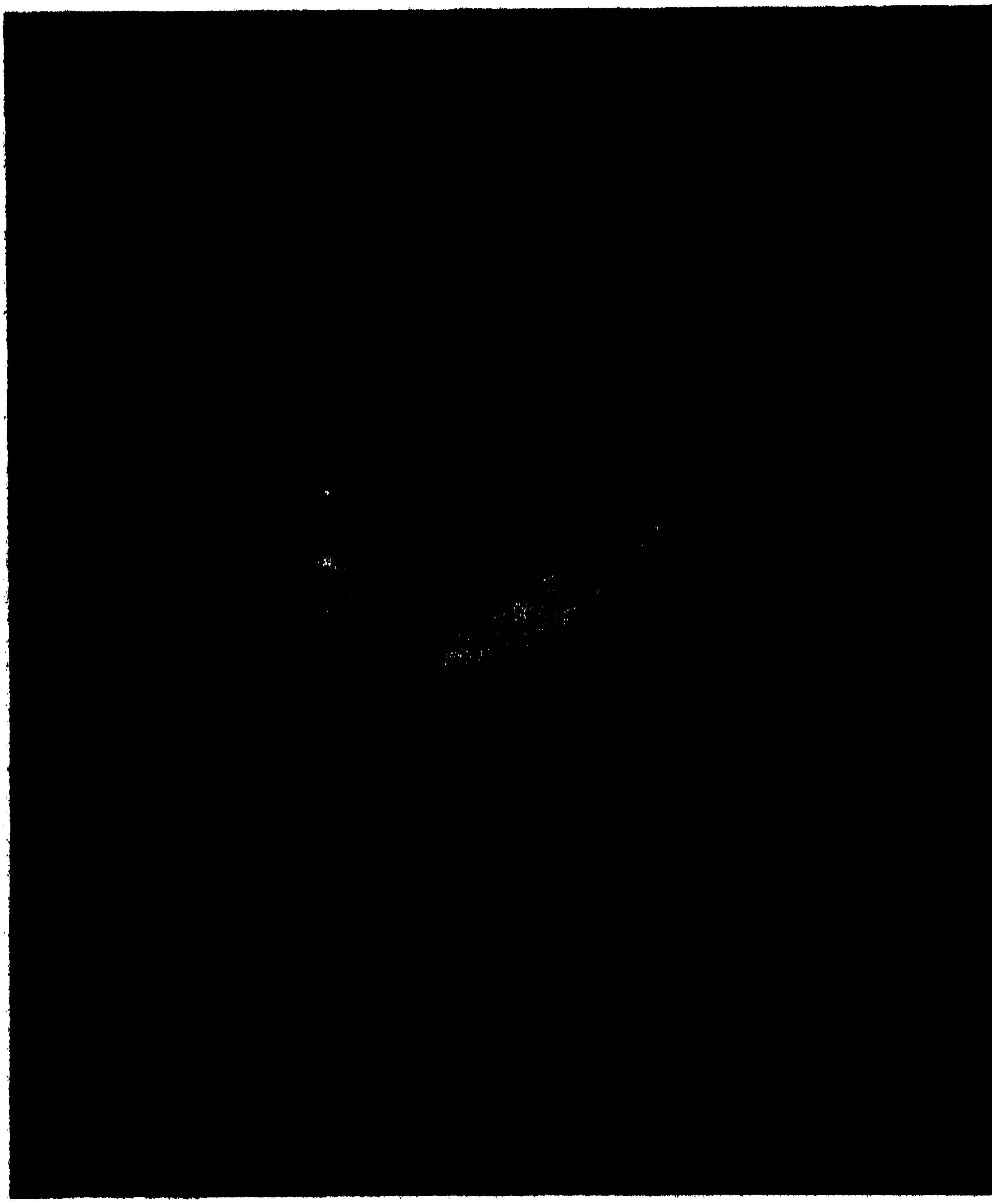
It was necessary to mention evidence

THE SAME DIFFUSE NEBULA

AS SHOWN ON ADJACENT PAGE. A PHOTOGRAPH TAKEN QUITE RECENTLY WITH THE 60-INCH REFLECTOR AT BLOEMFONTEIN, SOUTH AFRICA.

relating to stellar motions in connection with some of the typical structural problems that have already been considered. There exists, however, a group of galactic problems which deals specifically with the state of motion in our milky-way system and which may properly be discussed under the present heading.

The Oort-Lindblad theory has been remarkably successful in explaining the great majority of the observed regularities in the distribution of the stellar motions. The underlying conception is that of rotation around the galactic nucleus. A star like our sun moves approximately in a circle around the galactic center, with a rotational speed of the order of one hundred and fifty miles per second; the period of a single galactic revolution is for our sun of the order of two hundred million years. Because of the considerable concentration of mass in its nucleus the galactic system does not rotate like a solid wheel, but, according to Oort and Lindblad, the period of rotation decreases as stars that are, on the aver-

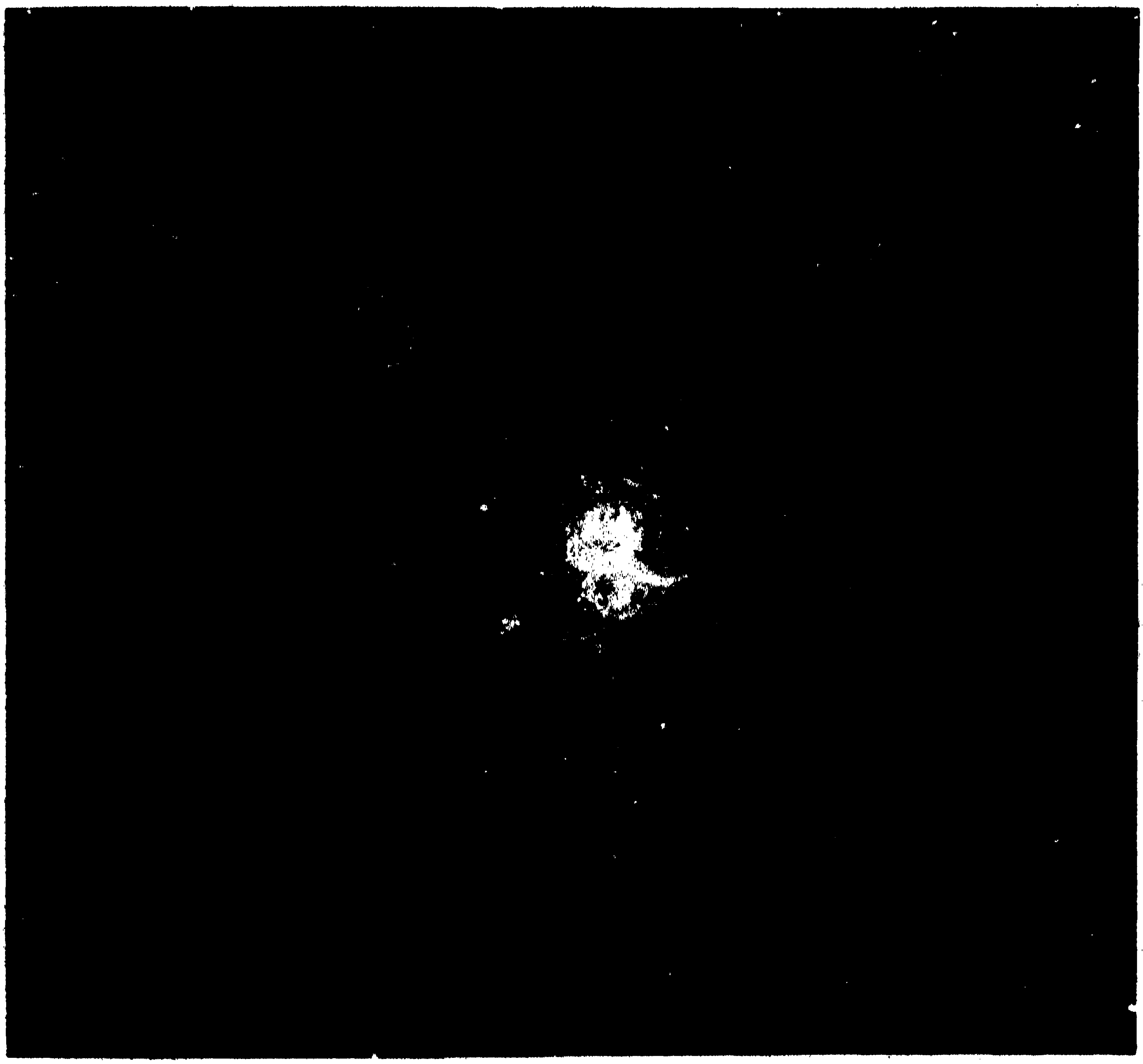


THE LARGE MAGELLANIC CLOUD

WHICH CAN BE CONSIDERED AS A SATELLITE OF OUR OWN MILKY WAY SYSTEM. SINCE IT IS OUR NEAREST EXTRA-GALACTIC NEIGHBOR IT IS POSSIBLE TO MAKE DETAILED STUDIES OF ITS STRUCTURAL FEATURES. THIS PLATE SHOWS THE APPEARANCE OF THE CLOUD AS A WHOLE. THE WHITE ARROWS POINT TO THE DIFFUSE NEBULA KNOWN AS 30 DORADUS, WHICH IS ALSO SHOWN ON ADJACENT PAGE.

age, closer to the galactic center are being considered. Viewed from the sun certain stars will appear to be running ahead, others will appear to be lagging behind, and some simple geometrical considerations show immediately what types of systematic effects should be observed in the average radial velocities and proper motions of stars at not too large distances from our sun.

The theory of galactic rotation was originally developed by Lindblad as a means for explaining a pronounced asymmetry in the distribution of stellar motions in the galactic plane which had been revealed by the work of Boss, Strömberg and Oort. It has been shown that the velocities in excess of forty miles per second with respect to our sun were all pointed toward one half of the galactic circle. The phenomenon of all high velocity stars rushing off toward one half



THE DIFFUSE NEBULA 30 DORADUS

IN THE LARGE MAGELLANIC CLOUD SHOWN ON ADJACENT PAGE. THIS PHOTOGRAPH IS FROM A PLATE BY DR. J. S. PARASKEVOPOULOS WITH THE 60-INCH REFLECTOR AT THE SOUTHERN STATION OF THE HARVARD OBSERVATORY. THE DISTANCE OF THE LARGE CLOUD IS ABOUT 85,000 LIGHT YEARS, ITS DIAMETER IS AT LEAST 15,000 LIGHT YEARS AND THE DIAMETER OF THE DIFFUSE NEBULA AMOUNTS TO 130 LIGHT YEARS.

of the milky way baffled astronomers until Lindblad hit on an explanation which in its simplest form is illustrated by the accompanying diagram.

G is the center of the galactic system, S is a star in neighborhood of the sun; the distance SG is therefore of the order of thirty-five thousand light years. If the velocity of the star S were equal to one hundred and fifty miles per second, the star would move in a circle around G. Our sun and the great majority of the nearby stars move apparently in such circular paths around the galactic center. There will of course be deviations from exact circular motion for each individual star, but the distances to the galactic center will, for most stars in the vicinity of the sun, vary by not more than five or ten thousand light years in the course of a few galactic revolutions.

Consider now the stars with velocities of (respectively) one hundred and two hundred miles per second around the galactic center. A velocity of one hundred miles per second at our sun will not

be sufficient to carry the star around in a more or less circular orbit, and the resulting orbit will have the elongated shape illustrated in the diagram. Such slow-moving stars do exist: an observer on our sun will recognize them as "high-velocity objects," which, viewed from his standpoint, have velocities of the order of fifty miles per second in a direction *opposite* to that of the general galactic rotation. The observed phenomenon of asymmetry shows that we do not find any stars that move with speeds of the order of fifty miles per second with respect to our sun *in* the direction of rotation. Such stars would have velocities of the order of two hundred miles per second with respect to the galactic center and the hypothesis of galactic rotation suggests that the gravitational pull of the galactic nucleus would be too small to keep them permanently in our system.

The simple explanation for the phenomenon of asymmetry in stellar motions can be refined in several ways, but the rough argument serves to show how this asymmetry is a natural consequence of the rotation of our galactic system. Astronomers had tried in vain to explain the asymmetry on the assumption that the motions of the stars near the sun were governed by the gravitational pull exerted by these same stars. The Oort-Lindblad theory showed that a distant galactic nucleus was the chief controlling factor.

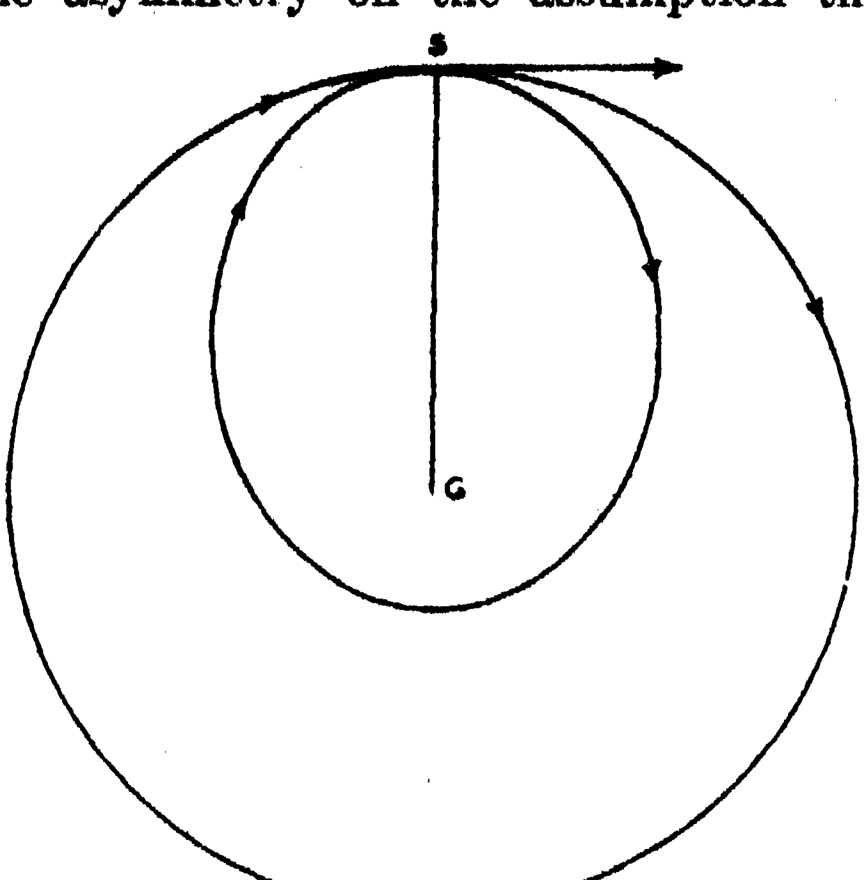
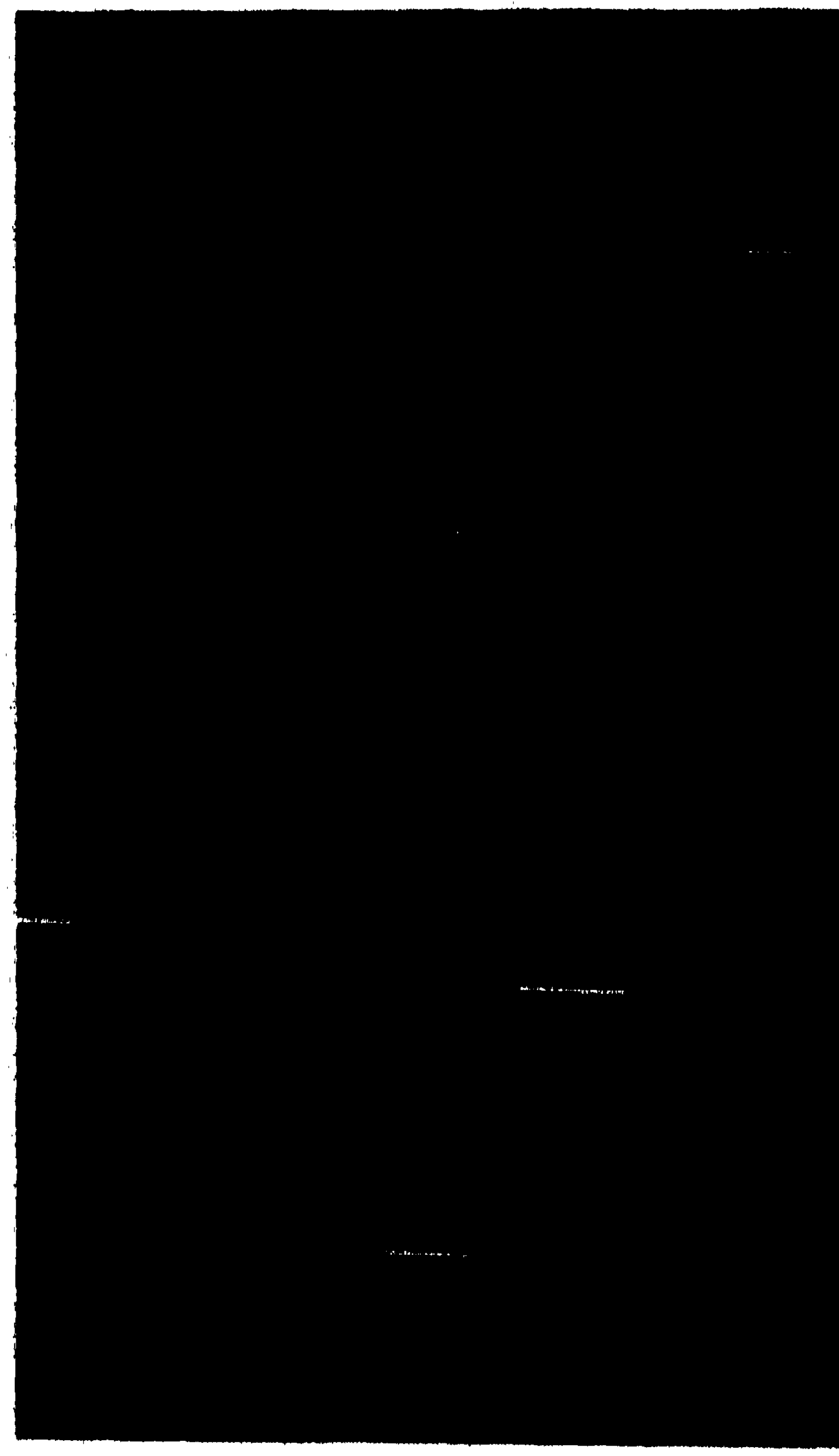


FIG. 2. THE THEORY OF GALACTIC ROTATION ORIGINALLY DEVELOPED BY LINDBLAD. *G* IS THE CENTER OF THE GALACTIC SYSTEM, *S* IS A STAR IN THE NEIGHBORHOOD OF THE SUN.



A PORTION OF A PLATE USED FOR THE DETERMINATION OF RADIAL VELOCITIES FROM OBJECTIVE PRISM SPECTRA FOR A FIELD IN MONOCEROS. THE PHOTOGRAPH WAS TAKEN BY DR. J. S. PARASKEVOPOULOS AT THE SOUTHERN STATION OF THE HARVARD OBSERVATORY WITH A SIX-DEGREE PRISM ATTACHED IN FRONT OF THE LENS OF THE 13-INCH BOYDEN TELESCOPE. THE ABSORPTION BAND MARKED "ND A," WHICH LOOKS VERY MUCH LIKE ONE OF THE STELLAR LINES, IS CAUSED BY THE PASSAGE OF THE STAR LIGHT THROUGH A LIQUID FILTER DIRECTLY IN FRONT OF THE PLATE WITH A SOLUTION MADE OF NEODYMIUM CHLORIDE. THE BAND ND A WILL HAVE THE SAME WAVE-LENGTH IN ALL STELLAR SPECTRA, WHEREAS STELLAR LINES H γ AND H δ WILL BE DISPLACED ACCORDING TO THE STAR'S RADIAL VELOCITY; ACCURATE MEASUREMENTS OF THE DISTANCES BETWEEN ND A AND H γ OR H δ WILL LEAD TO A DETERMINATION OF STELLAR RADIAL VELOCITIES.

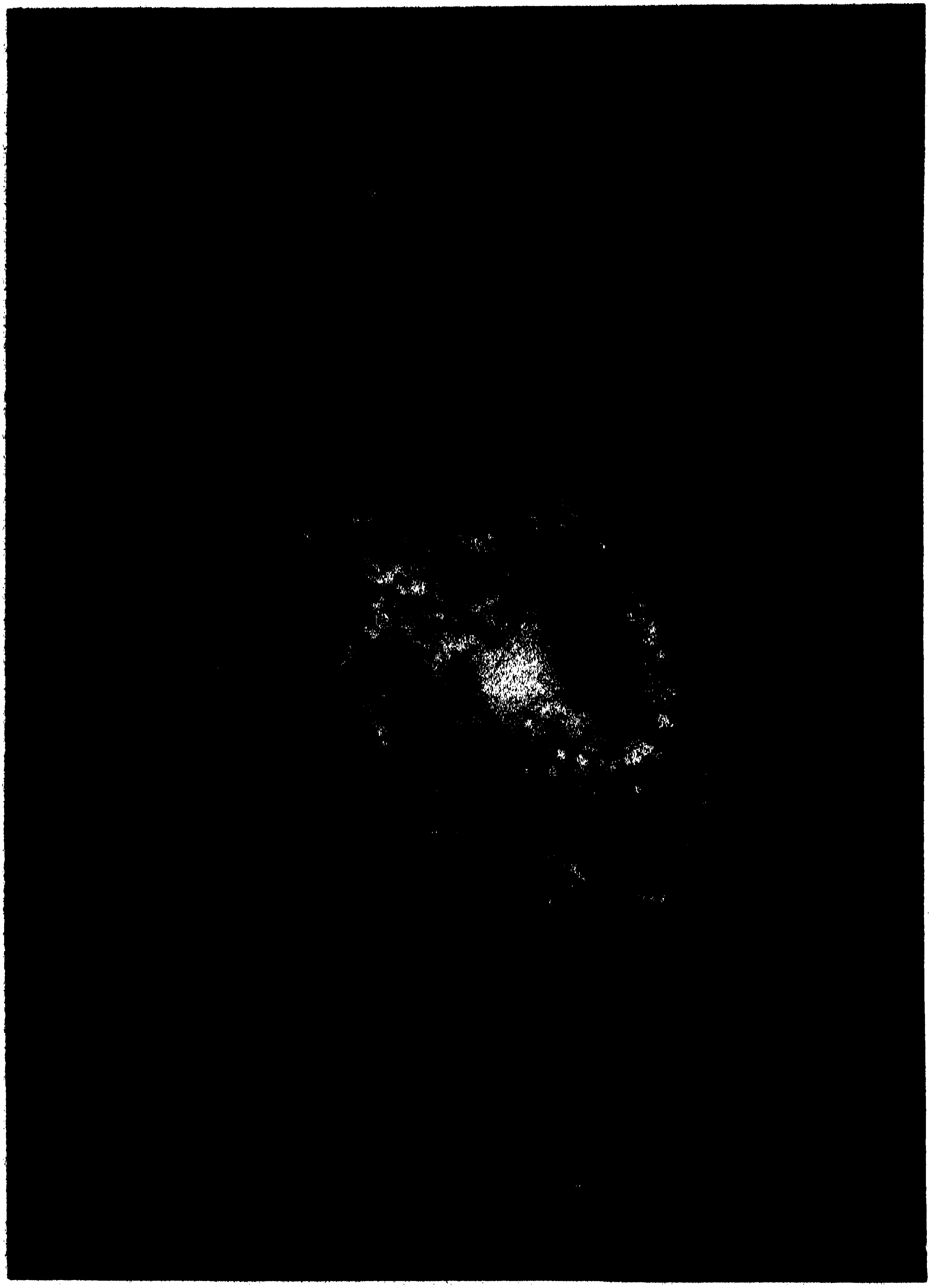
Lindblad pointed out that the theory could also account in a satisfactory fashion for the two star streams, discovered by Kapteyn in the first decade of the present century. When Oort succeeded in demonstrating from the observed stellar motions that the predicted variations in the average velocities of distant stars existed, the theory of galactic rotation could rightfully boast of three major victories. But again there remained, and still remains, a lot to be done!

The primary need is for further data about the line-of-sight velocities of distant objects. Important contributions have been made in recent years by Plaskett (giant stars with high temperatures), Joy (faint Cepheid variables) and Berman (planetary nebulae). The results of these studies have strengthened the observational foundations on which the hypothesis of the rotation of our galaxy is based. The two outstanding defects of the available material are: (1) an insufficient number of velocities for faint stars; (2) an uneven distribution of the stars with known velocities along the milky way. A distressing lack of radial velocity data in the southern hemisphere has arisen because of the location in northern latitudes of most of the telescopes used for radial velocity work. A large British observatory to be established in South Africa near Pretoria will undoubtedly do its best to fill in that particular gap. Also, during the past two years the objective-prism method of obtaining radial velocities for large numbers of faint stars has been adapted for use with the Harvard Observatory's instruments at the station at Bloemfontein, South Africa. There is now in progress at Harvard a study of the distribution of the radial velocities of a thousand stars in twelve fields, located at intervals of thirty degrees around the entire milky way.

Highly significant results may be expected from investigations dealing with the velocities of very distant stars and nebulae. The theory of galactic rotation predicts for such objects certain deviations from the simple effects observed for the stars within five thousand light years of our sun. It should be possible to obtain information on the distribution of mass in the galactic nucleus, if we can observe stars near enough to the galactic center. Valuable results may be expected from the measurements of radial velocities for galactic clusters (Trumpler) and globular clusters (Mayall) which are under way at the Lick Observatory. It will, however, be advisable in the interpretation of the data of observation not to place too much implicit faith in the simple theory of galactic rotation. The Oort-Lindblad theory supposes our milky-way system to be a structureless affair in which a massive nucleus alone determines the motions of the stars. The case is not unlike that of the smooth all-pervading interstellar medium that was originally held responsible for all absorption phenomena. The smooth medium was soon forced to abdicate in favor of the complex interstellar medium revealed by recent studies, and the same fate will undoubtedly await the simple theory of galactic rotation.

The nearby stars should also come in for their share of attention. Several observatories have undertaken the time-consuming job of providing further velocity data for the stars within two or three thousand light years from the sun. Before another decade will have passed we may count on having detailed information on the local irregularities in the distribution of stellar velocities. These observations may well yield the information needed for the formulation of a hypothesis on the distribution of stellar motions that takes into account some of the more complex features of galactic structure.

Apparently this is the age in which the galactic investigator is constantly clamoring for more observational material. At the same time it is well, however,



THE SPIRAL NEBULA MESSIER 83

A RECENT PHOTOGRAPH OF THE SPIRAL NEBULA MESSIER 83, TAKEN WITH THE 60-INCH REFLECTOR AT THE BOYDEN STATION OF THE HARVARD OBSERVATORY. THE APPEARANCE OF OUR MILKY-WAY SYSTEM, AS VIEWED BY AN ASTRONOMER LIVING SOMEWHERE IN MESSIER 83, MAY NOT BE UNLIKE THAT SHOWN IN THE ABOVE PHOTOGRAPH.

to remember the need for further theoretical investigations. Our galactic system may be a spiral nebula. What state of motion is to be expected in such a nebula? How did the many spiral nebulae that are known come into existence and what guesses can we make about their possible development? Such questions lead to dynamical studies of great difficulty, to which Lindblad has paid particular attention during recent years. It appears that the good old Newtonian law of attraction may after all succeed in explaining the nature of spiral arms and that there will be no need to invent mysterious "cosmic forces" to account for the prevalence of spiral structure in the universe of galaxies.

A second theoretical question that still keeps astronomers guessing is related to the origin of our milky way system. It has long been known that there exists a correlation between the velocity characteristics of the stars and their physical properties. For instance, there are indications that the blue-white giant stars move in more or less circular orbits around the galactic center, while the red giants appear to prefer more elongated ones. Also we find among the Cepheid variable stars that the variables with periods of light variation of the order of ten days move in circular paths, whereas Cepheids with periods around one day are found to have orbits that are definitely elongated. This difference must be somehow related to the beginning of our galactic system and the origin of stars. At present it does seem absurd that the periods of light variation, which depend on conditions in the stellar interiors, should be correlated with the speeds of the stars. But absurd or not, we have to face the facts and we should admit that we have as yet mighty little to offer for an explanation.

A question of great importance for all theoretical studies of our galactic system is that of its probable age. A most delicate question indeed! This is not the place to go into details about the controversial subject of the age of the universe, but it is well to remember in all theoretical investigations that our sun has probably not gone more than twenty times around the galactic center. The stars still exhibit a surprising degree of parallelism in the distribution of their motions. This in itself offers pretty good evidence that our system is still fairly young. As time progresses stars should influence one another's motions to a considerable extent; it is for instance difficult to understand how the members of the loosely-connected Hyades cluster could continue to run very nearly parallel for more than a few galactic revolutions. Several independent lines of evidence suggest that approximately three billion years ago our galactic system underwent some rather drastic punishment. What exactly did happen at that time? That is just another problem for the astronomer to solve, but before we tackle it we had better get first some more information on what goes on right now.

The recent advances in our knowledge of galactic structure have been brought about largely by the development of very efficient instruments. The progress of the past forty years has depended at each point on refinements and improvements in the technique of observation. The total amount of information that is needed is so large that there simply has not yet been enough time to get it together. The gaps in our knowledge are, however, being filled in rapidly, and I can only hope that the answers to some of the problems which I have posed may make interesting reading before another decade will have passed by.

LIFE IN THE SEA. II

By Dr. R. E. COKER

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GASES IN SOLUTION

The chief gases dissolved in the sea are nitrogen, oxygen and carbon dioxide. Nitrogen is said to occur in sea water in somewhat smaller proportion (64 per cent.) to other gases than in the air (78 per cent.), but in approximately saturated solution. Oxygen is about one fifth less soluble in sea water than in fresh water, but it is absorbed in sea water in a proportion to other gases (34 per cent.) substantially greater than in the air (21 per cent.). The percentages given apply to sea water at the surface with salinity of 3.5 per cent. and temperature of 10° C. These figures, indicating the proportion of the several gases relative to one another in dissolved, as compared with atmospheric air, are perhaps of less practical significance than are those indicating the volumes of oxygen in a liter of sea water at the point of saturation—and this varies with the temperature, the pressure and the salinity. At any given temperature and pressure, sea water can hold in solution less oxygen (about one fifth less) than can fresh water, as is indicated by Table II. (After Fox, from Murray and Hjort, p. 254).

TABLE II

SOLUBILITY OF OXYGEN IN FRESH AND SEA WATER AT DIFFERENT TEMPERATURES*

Temperature	Fresh-water salinity 0 per M.	Sea-water salinity 35 per M.
0°	10.29	8.03
10°	8.02	6.40
20°	6.57	5.35
30°	5.57	4.50

* Under conditions of atmospheric mixture and under a pressure of one atmosphere.

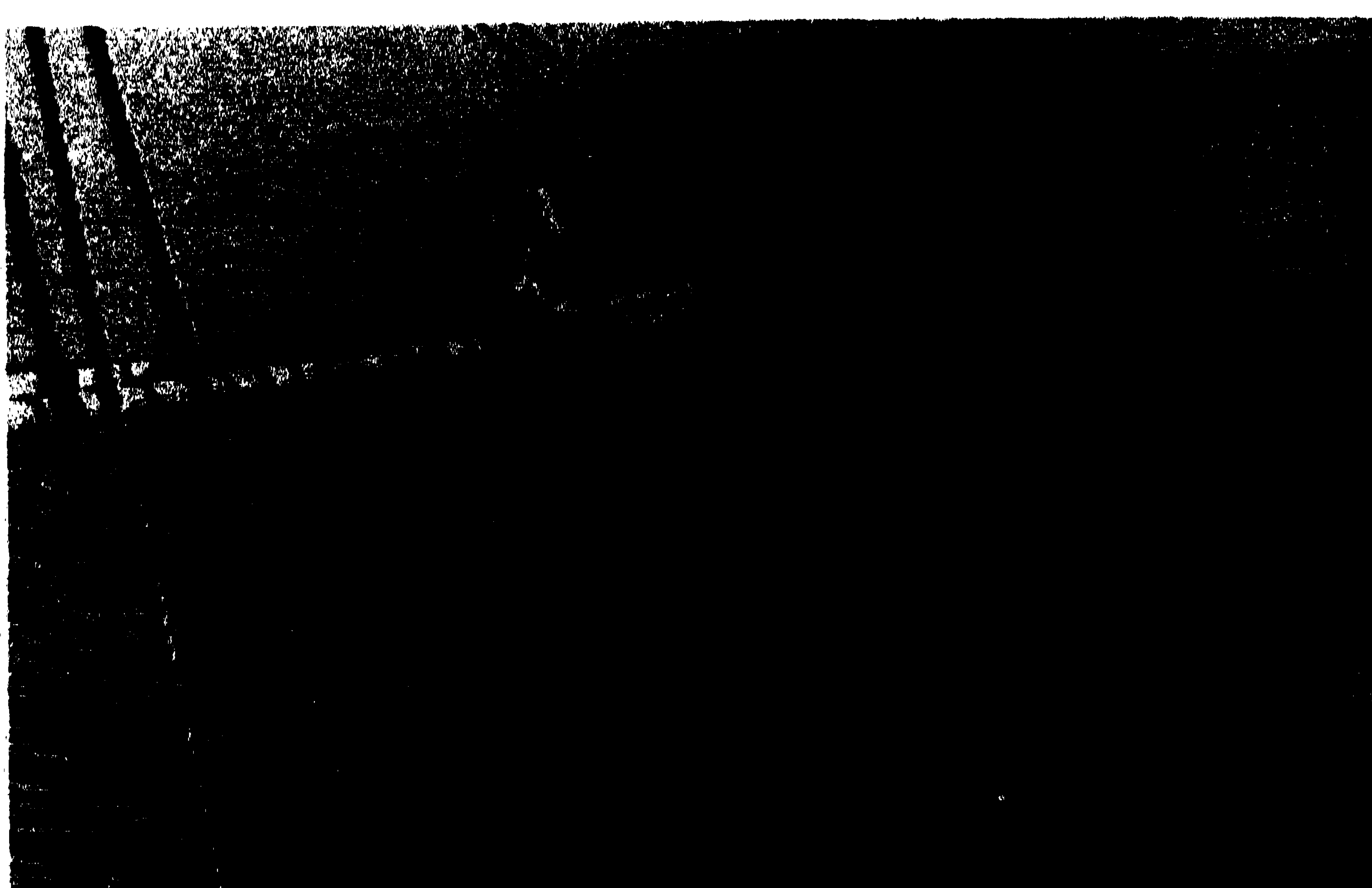
The free oxygen in sea water is derived partly from the atmosphere by absorption at the surface and partly from the photosynthetic activities of plants. The photosynthetic zone, as we have seen, is a superficial stratum some hundred of meters, more or less, in depth, but it does not follow that the plants throughout all the depths at which they may live are *net* contributors to the supply available for animals. In the deeper zones, inhabited by plants, they may consume as much or more oxygen than they produce, so that the net contribution is nil or a minus quantity. The level at which oxygen consumed and oxygen produced are in balance is called the "compensation point"; in the Gulf of Maine in June, 1934, this was at 24–30 meters.[16]

Carbon dioxide is soluble in sea water in about fifty times the proportion in which it is found in the atmosphere, but even that is a very small proportion: approximately 1.6 per cent. by weight in sea water as compared with 0.03 per cent. in atmosphere. Carbon dioxide is also present in sea water in "bound" and "half-bound" condition—in combination with minerals as carbonates and bicarbonates. "There is usually about 50 cc. of carbonic acid in one liter of sea water (as compared with 5–10 of oxygen), but of this only a few tenths of a cubic centimeter is free gas in solution" (Murray and Hjort). Carbon dioxide is certainly not consumed by green plants below some 1,000 meters, and doubtless rarely at that depth, although it must there be produced in quantity both by the respiration of animals and the decomposition of organic material. What then becomes of that part of it which may not enter into chemical combination with dissolved min-

[16] Clarke and Oster, 1934, p. 71.

erals? Are the vertical movements of water sufficient to maintain the proper equilibrium of dissolved gases in the depths?

Since the solubility of gases in water varies inversely with the temperature, the cold waters of the Arctic are much richer than tropical waters, in both dissolved CO_2 necessary for photosynthesis and dissolved oxygen necessary for the respiration of animals. Cold waters, being heavier than warmer waters of like salinity, tend to seek the bottom, and abyssal waters of all oceans are presumed to be derived in considerable part from the polar regions, particularly from the Antarctic, and to have been originally especially rich in oxygen. Surface waters are generally supersaturated. Deep waters might be supposed to be generally poor in oxygen, since the dissolved gas is used both in the respiration of abyssal animals and in the decomposition of organic materials which have settled to the bottom from the waters above and also because, in the absence of photosynthesis resulting from the lack of light, no oxygen is liberated there. Mixing (overturn) occurs in high latitudes, as we have seen, and especially in or at the end of winter when the colder heavier waters of the surface laden with oxygen sink to a lower level to replace the somewhat lighter waters which rise to the top to become reoxygenated. Nevertheless, the actual conditions do not conform to a rule that may be simply stated. Bottom waters, especially in the Atlantic, where they may be 75 per cent. saturated, may contain more oxygen than layers far above them. Seiwell (1937) observes that the minimum concentration of oxygen in the western North Atlantic is generally between depths of 200 and 900 meters, with values ranging from 1.7 to more than 5.0 cc per liter. Vaughan says that there is in the eastern Pacific, usually between 600 and 1,200 meters, a layer where



THE BIOLOGIST, MR. SEIWELL

MAKES A SURFACE DIP FROM THE BOOM WALK ON THE "CARNEGIE." COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

Photo by Colt Coker.

ATTACHING A METER NET TO THE TOWING CABLE FOR COLLECTING PLANKTON

ON THE "ASTERIAS" OF THE WOODS HOLE OCEANOGRAPHIC INSTITUTION. SEVERAL SUCH NETS MAY BE USED AT DIFFERENT DEPTHS ON THE SAME CABLE.

the water is only 5 per cent. saturated with oxygen, while below that the maximum saturation may range between 30 per cent. and 40 per cent.

The conditions of life of all animals and plants in the sea and in other waters, as compared with those of terrestrial organisms, are marked by this important distinction—that the requisite gaseous oxygen occurs in relatively extreme degree of dilution. A liter of air contains 25 or more times the amount of oxygen that can be dissolved in a liter of sea water. Free carbon dioxide, on the other hand, may occur in approximately the same volume in sea water as in the atmosphere.

CONDITIONS OF LIFE IN THE DEPTHS

In the depths of the sea there is, of course, a great stillness—no wave movements, no tides, no vibrations; even the slow drifts, horizontal or vertical, traceable to conditions of wind, temperature or salinity elsewhere, as well as to the rotation of the earth and extra-terrestrial influences, can scarcely be felt.[17] The very build of some of the inhabitants of the great depths would render them quite incapable of taking care of themselves at the surface: the greatest living crustacean, *Kaempfferia kaempfferi,* five meters in expanse of limbs, would be utterly helpless in wave-disturbed waters. The abyssal regions may then be thought of as regions of utter darkness, almost absolute stillness, tremendous pressure, very low temperature and limited supply of free oxygen; and, of these, the amazing pressure is of perhaps the least biological significance. Such are the conditions under which the denizens of the deep may appropriately be said to "pursue the even tenor of their ways." There can be comparatively little local or seasonal variation in the conditions of existence. From east to west and north to south, under the tropics or beneath the Arctic and Antarctic circles, from June to December and from December to June, there is no change in the conditions of light, because there is no light beyond such momentary flashes as may be produced by the light organs of abyssal animals; there are no pronounced differences in temperature, no storms and virtually no perceptible currents. From place to place there may indeed be con-

[17] So, at least, we picture provisionally the conditions that no one can directly observe. Future knowledge of deep tidal and turbulence phenomena may necessitate some slight retouching of the picture.

siderable differences in pressure, in character of bottom and in food supply, but in most regions such differences, other than those in pressure, would presumably be encountered very gradually and at the cost of considerable travel.

It is not remarkable that the idea once held sway that the floor of the sea beyond the Continental Shelf was without life, a great desert, an azoic area: in this pitch-blackness, whence could come the supply of free oxygen to support animal life? In temperate and Arctic regions, wherever the surface waters may at times be brought to a temperature at which it is heavier than the waters below, they will, of course, sink toward the bottom to be replaced at the surface by lighter waters from the depths, and so, by this "overturn," the oxygen supply of abyssal waters of the region is renewed; but, over a great part of the Atlantic, Pacific and Indian Oceans, such a condition can not occur. Animals yet thrive at the bottom, presumably utilizing oxygen brought by the slow drifts of cold and richly oxygenated waters from polar regions. Probably the abyssal animals are not very abundant and lead slow lives, involving a minimum oxygen demand.

ORGANIC LIFE IN THE SEA

The Requirements of Life

In a general way the necessities of life are the same in the sea as on land: water, sunlight, heat, oxygen, carbon dioxide, food (in the form of the building materials of protoplasm and the fuel to supply energy), protection from enemies and, we might add among the necessities, enemies themselves or some means of keeping a particular population in equilibrium with its food supply. Our previous discussion has dealt adequately enough for the present purposes with the occurrence and distribution of all these requirements except the last three—food, protection and enemies.

Considering the last of these three first, the enemies of a species may generally be accounted useful to the species; since, without some control upon the increase of a population, such as is afforded by its predators, multiplication in numbers must inevitably outrun the food supply and lead to starvation. At any rate we know nothing of the existence of organisms without effective enemies and parasites. On the other hand, protection or refuge from enemies is equally essential—both for the prey and for the enemy. The predators may serve a useful purpose to themselves and to their prey as they keep the multiplication of the prey within bounds. But the prey must, in the interest of both parties to

Photo by Coit Coker.

TOWING A SURFACE NET FOR PLANKTON

FROM THE "ASTERIAS" OF THE WOODS HOLE OCEANOGRAPHIC INSTITUTION.

HAULING IN THE PLANKTON NET ON THE "CARNEGIE"
COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

the contract, have some means of regulating the extent of the depredations made upon them.

On land, in fresh water and in coastal waters, there exists for animal life what is called shelter or refuge in the thickets of vegetation which play a significant part in preserving some sort of balance between the warring members of the community—in short, between consumption and supply. In the picture that has been given of the open sea, that is to say, of what is by far the greater part of the oceans, we must have been impressed with the entire lack of refuge. Where the vegetation is composed exclusively of plant bodies of microscopic size scattered and free floating—in this sort of diffuse and open pasture there is no place of hiding. Survival or death for plants and for the animals of feeble powers of locomotion, which includes the vast majority of plankton animals, depends upon the accidents of the presence and state of hunger of the potential consumer. Transparency of body is a chief resort for concealment, and prolificness in production the strongest hope of survival of the species. Transparency means high water content and, as Ostwald remarked long ago, no organisms are so rich in water as the inhabitants of the open waters of lake or ocean.

Wherever shelter occurs in the sea it is availed of. Clams, worms and crustacea burrow in the bottom, and even in rock, or find concealment among the shells of the bottom. The discarded shells of conchs become the houses of hermit crabs. Oyster beds and thickets of eelgrass harbor a rich and varied population of small plants and animals. The sargassum weed, which occurs in large floating gardens, offers one of the rare refuges of the ocean proper, and the extensive masses of weed are true zoological gardens: they afford shelter to what, to the uninitiated, is an astonishing community of fish, mollusks, crustacea and other animals which manifest the most bizarre forms in correspondence with their peculiar habitat. Still other animals find refuge within the bells of jellyfishes. Many other instances of the intrusion of animals into every available form of refuge could be cited; but all these will account for but a small part of the life in the sea. The ocean generally is a place without tangible refuge. We know little, of course, of the conditions of life on the bottom, but, above the bottom, protection for the small organisms that predominate must depend upon

translucency or other means of making their bodies inconspicuous or upon the ability to live in the darkness below the upper illuminated zones. We know of no considerable habitat on land where want of refuge prevails in a way at all comparable to that which marks the greater part of the surface of the earth, occupied as it is by the open sea.

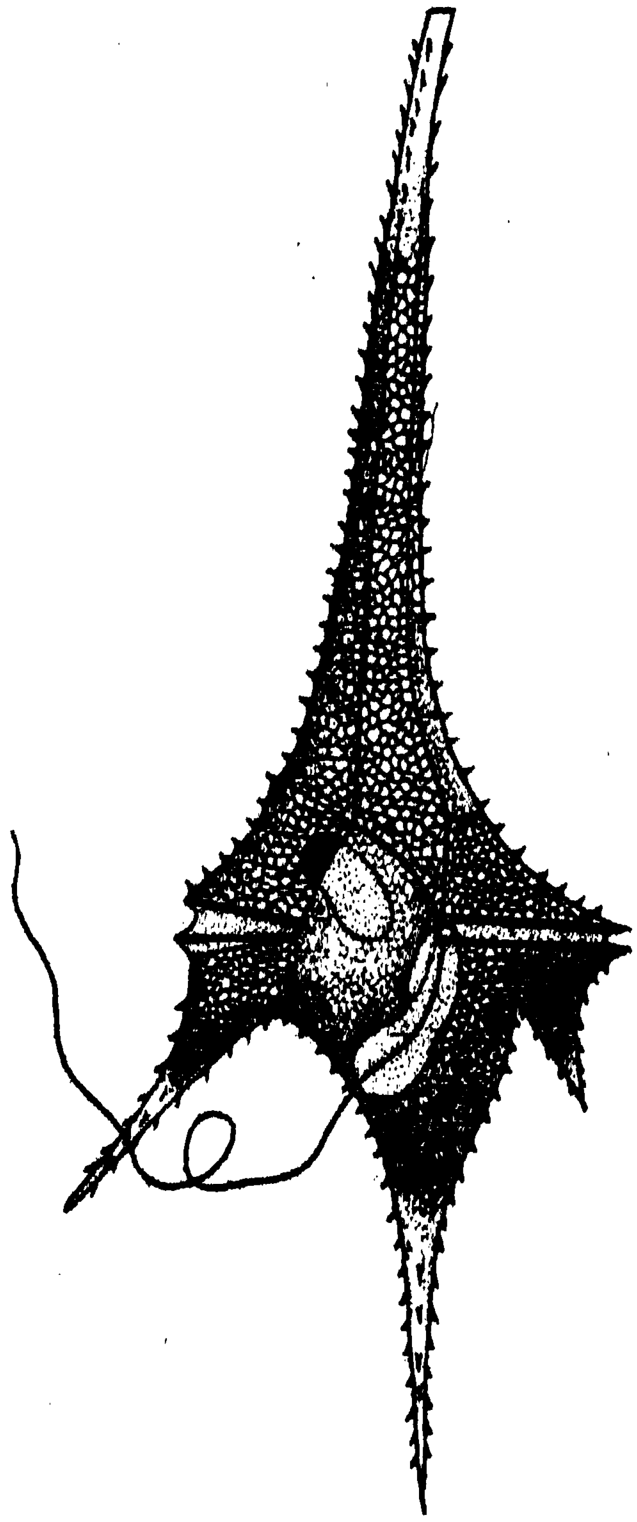
Finally, as regards food, we have in the sea, as on land, a great organic cycle in which organisms feed and sooner or later serve as food. The food cycle might be said to begin with the utilization of inorganic materials by green or yellow or brown plants, to run through the chain of vegetarian animals and carnivores, to continue with the reduction of organic wastes by bacteria of decomposition, and thus to begin again.

Before passing to a consideration of the kinds of plants and animals that live in the sea, we might recall Haeckel's classification of aquatic organic life by mode of living, as Benthos, Nekton and Plankton, the last being Hensen's terms. Benthonic animals or plants are those that live in close association with the bottom or with relatively fixed objects: worms that burrow, crabs that crawl, snails that creep over plant stems, barnacles that are attached to any available object, living or dead, etc. The nekton comprises animals that rove freely in the water, having no necessary connection with the bottom: fish, squid, whales, etc. The plankton is comprised of the plants and animals, generally small and with bodies scarcely heavier than sea water, that have limited powers of locomotion and that are therefore carried about by the currents. The classification is not all-inclusive, and there is no sharp line between the several groups. Nevertheless, it has some convenience, and the term plankton, at least, has become practically indispensable.

As we have suggested on an earlier page, the seas, in spite of their continuity and relative uniformity in proportions of the several mineral salts in solution, do not constitute a single habitat, and the life in the sea does not compose a single community. This applies not only to the animals and plants that live along the shores of continents and islands where the fauna and flora is richest and where the differences in habitats are observable by any one, but also to the plankton or drifting organisms as well. As knowledge of the plankton has progressed, with qualitative and quantitative studies in various parts of the ocean, it is now even surprising that some serious students once conceived of a uniform distribution

A HEAVY CATCH IN THE LOWER PART OF THE PLANKTON NET

FAR MORE THAN THE "BUCKET" CAN HOLD. PHOTO FROM THE "CARNEGIE." COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.



A DINOFLAGELLATE PROTOZOAN OR PROTOPHYTE, *CERATIUM HIRUNDINELLA*
(FROM KUDO AFTER STEIN.)

of floating life in the open ocean. It is elementary knowledge now that there is great diversity in the composition of plankton, not only in different regions and at different depths, but also at different seasons and at different hours at the same place and depth and probably even in different years.[18] The conditions that lead to maxima and minima, as well as to minor fluctuations of abundance of any particular plant or animal, are complex indeed in their physical, chemical and biological aspects.

We are fundamentally wrong in our conception of the plankton, if we do not picture it as always and everywhere in process of change. At any spot changes may occur in the kinds of animals that are present and in the relative and absolute numbers of the several kinds of animals and plants. We might conceive of the sea with its drifting minute life as like a sky of great depth full of clouds of very unequal densities, clouds that rise or fall, drift from place to place, and become heavier or lighter. Perhaps in some parts of the sky, particularly those remote from the horizon, the clouds, though variable, are always thin. In other regions, the variations in density may sometimes show a decrease to extreme dilution or, again, an increase to the point of oversaturation, followed, in the case of the clouds in the sky, by precipitation, or, in the case of the plankton, by mortality—in either case by a relative clearing. Such an analogy would, however, fall far short. The clouds in the sky have a single component, water vapor, and they vary only in degree of concentration of this one thing. The plankton clouds have a few dozen of components, the proportions of which are most inconstant. We should have to go much farther, indeed, and imagine that the several distinct kinds of droplets in the clouds could multiply, could devour each other and could be individually precipitated.

PLANT LIFE IN THE SEA

Such frequent allusion has already been made to the vegetation in the sea that we may now deal very briefly with this, the greater part of the organic world: for, after all, vegetation is the broad base of the pyramid of life in the sea. The contrast to conditions on land

[18] Bigelow (1926, p. 78): "Even a cursory examination of the Zooplankton, if extended over a considerable area or through a considerable period of time, is certain to reveal wide fluctuations in abundance as well as in its qualitative composition, both from season to season and from place to place." Allen (1934, p. 172): "From this and other evidence accumulated by the Scripps Institution over a period of thirty years it appears certain that uniformity of distribution of plankton in sea water, either horizontally or vertically, is practically nonexistent in Southern California waters at any time, whatever may be the condition in some other oceanic locality."

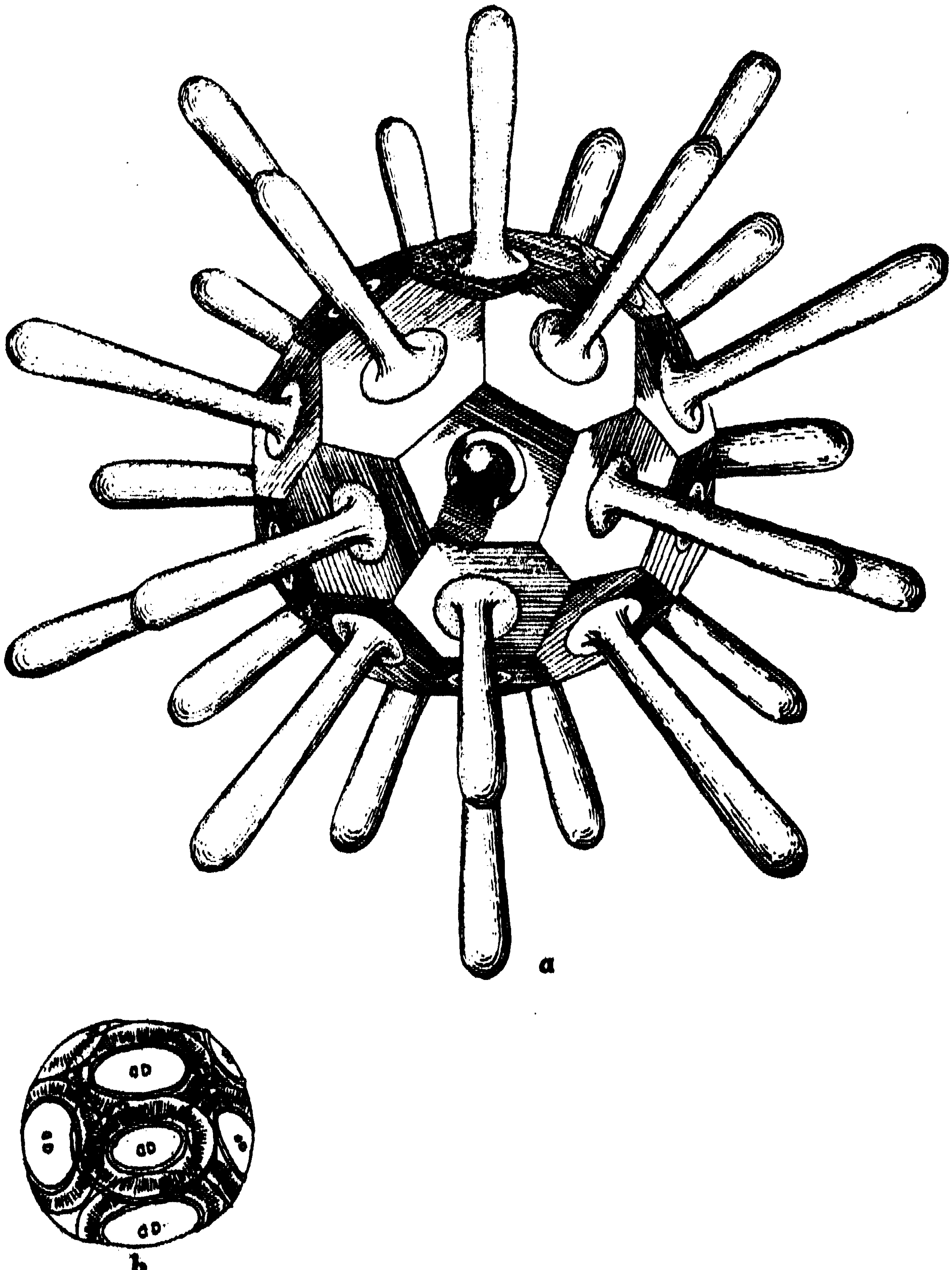
is marked. None of the higher plants occur in the ocean remote from the shores. Seed plants are totally wanting, and mosses and ferns as well. Even along the coasts the larger algae are chiefly of groups not represented on land or in fresh waters. The great group of blue-green algae, abundant in lakes and rivers, are prominent in the ocean only in waters near the mouths of large rivers or in tropical regions. The green algae, predominant in fresh waters, are sparsely represented in salt water and then chiefly where there is some admixture of fresh water. On the other hand, brown and red algae, richly present in the benthonic life of the ocean along and near the coast, are most sparingly represented in fresh waters. Brown algae, including rock weeds, sargassum and kelps, are the largest and most conspicuous of coastal marine algae: the more delicate red algae on the bottom extend farther out into the sea, living not only in harbors and along the shores but also in the deeper waters of the Continental Shelf beyond the depths of penetration of the shorter rays of sunlight necessary for the growth of true green plants. The red algae are, therefore, presumably of special significance as "producers" or photosynthetic agents on the Continental Shelf.

The brown seaweed, Sargassum, is the only large seaweed that finds a prominent place in the high seas. Breaking loose from the rocks to which it is attached along certain shores, it drifts in the currents, multiplying vegetatively as it goes, and accumulates in the great eddy in the Atlantic Ocean known as the Sargasso Sea. Here, as it grows and before it dies to sink and decompose, it forms an extensive shelter for a remarkable special community of animals, many of which can live nowhere else than in the clumps of Sargassum.

The off-shore plant life, barring the floating Sargassum, is, as we have repeatedly observed, of extreme simplicity of form. Even the relatively simple filamentous forms so characteristic of all sorts of fresh water are missing. Conditions in the sea have not favored cell aggregations and the associated specialization in form and development of larger bodies.

There is, indeed, a marked paucity of green algae. The Chlorophyceae are represented in the open sea chiefly by a single species, *Halosphaera viridis,* which, although minute in size, has yet caught the eye of Mediterranean fishermen who long ago named it "Punti verdi" (green points). On the other hand, the unicellular algae called diatoms, with siliceous shells, and the dinoflagellates (some plant-like, some animal-like), occur abundantly in both fresh and salt water. But, except for bottom-living diatoms, it is in the sea that the plants of both of these groups attain their fullest flower. Great areas may be discolored by them. The conspicuous "red seas" that arrest the eyes of voyagers and are many square miles in extent are sometimes at least attributable to immense swarms of dinoflagellates. Again, the surface waters for miles and miles may be discolored and actually "soupy" with diatoms. All the plankton algae are, of course, restricted to the upper few hundred meters except as their falling bodies may invade the regions of darkness below.

Still smaller are the Coccolithophoridae which are said to constitute a large proportion of the marine planktons, but which pass through the finest silk nets and must be sought by centrifuging. The name means "bearers of coccoliths," for the minute bodies are protected by calcareous plates or spicules of the order of size of bacteria and long known as a substantial component of deep sea calcareous deposits, especially the Globigerina Ooze. These algae (or protozoa) are of the group of yellow flagellates called Chrysomonads, to which belong also Dinobryon, a fresh-water algae that



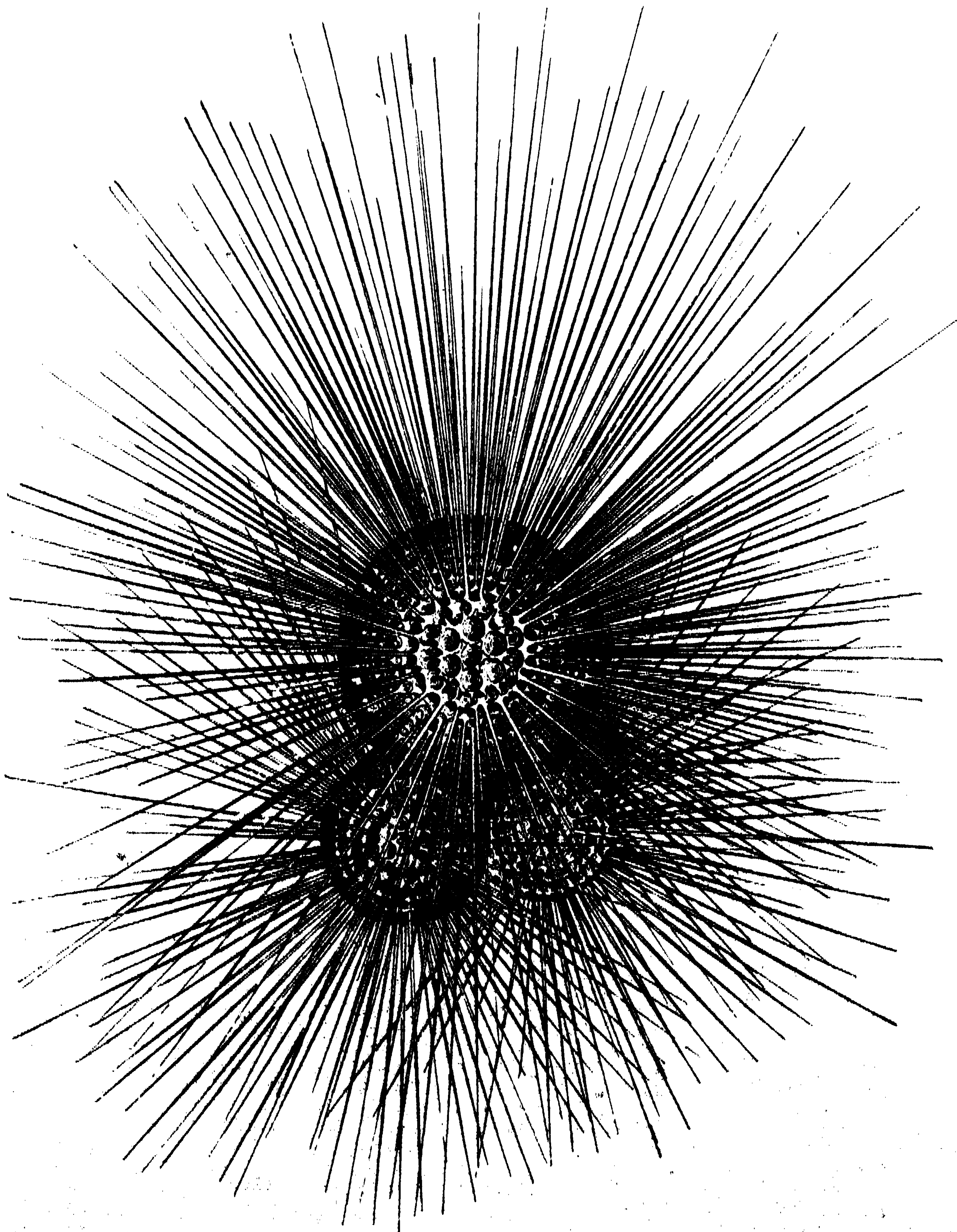
COCCOLITHOPHORES
(a) *Rhabdosphaera claviger* (AFTER MURRAY AND HJORT).
(b) *Coccolithus pelagicus* (FROM FRITSCH AFTER LEBOUR).

sometimes occurs in such abundance as to discolor the water of lakes and ponds. The Coccolithophoridae seem to be universally distributed in the oceans except in the colder waters of polar seas.

We have passed over the bacteria, which, according to some accounts at least, are not notably abundant in the sea, although as yet comparatively little is known of the bacteria of the bottom. There is nothing in the conditions of temperature and pressure in the bottom to prevent the growth of bacteria (ZoBell). Experiments of Clarke and Gellis (1935) "indicate that bacteria and other constituents of the nannoplankton may be an important food for copepods in the sea." Bacteria may serve to some extent as synthetic agents in regions of the sea where green plants can not function, but we have too little information concerning the significance of bacteria in the ocean.

Although the higher plants are com-

pletely wanting in the open sea, we should refer to a seed-plant that is commonly of considerable significance in coastal waters and perhaps beyond. The common "eel-grass," Zostera, a flowering plant of the pond-weed family, occurs on almost all ocean shores where wave action is not severe. Its abundance and general distribution is indicated by the windrows of it seen on beaches of harbor and ocean. As the annual crops of eelgrass die and are broken to pieces, the fine detritus to



THE PROTOZOAN, *GLOBIGERINA BULLOIDES* D'ORBIGNY
(AFTER MURRAY AND HJORT.)

which it is ultimately reduced may be carried well out to sea to constitute a basic food supply for many kinds of animals. Some biologists have indeed attached greater importance to the detritus formed from eelgrass grown in shallow waters than to the phytoplankton multiplying in the offshore waters as the support of animal life in the ocean. A remarkable phenomenon and one not yet adequately accounted for, has been the recent and comparatively sudden disappearance of eelgrass on both sides of the Atlantic and on some Pacific shores, apparently as the result of or with the accompaniment of some sort of disease. Apparently this disaster to eelgrass and, of course, to many of the animals associated with it, is not entirely without precedent, but why does the disease appear so suddenly and in such wide-spread fashion?

In summary as regards plant life in the sea, those species of plants that are visible to the eye play a minor part in the "metabolism of the sea," and emphasis must be placed on the minute species. "This," says Brooks (1893) "is the fundamental conception of marine biology: The basis of all the life in the modern ocean is to be sought in the microorganisms of the surface."

ANIMAL LIFE IN THE SEA

Comparison of Oceanic and Other Faunas

With such a contrast as prevails between the forms and sizes of plants in the ocean and on land, respectively, it is to be expected that there would be a corresponding contrast in respect to the sizes of the primary consumers of plants. Brooks long ago remarked on the apparent scarcity of vegetarian animals in the ocean. All the familiar animals are carnivorous; there are no great groups in the sea corresponding to the order of rodents on land or to the plant-eating birds and insects, to say nothing of the larger browsing and grazing animals such as deer, horses, cows, elephants, etc.; yet, according to the principle of the pyramid of numbers, the vegetarian animals must greatly outnumber the carnivores. These are actually present in enormous numbers, but individually they are quite small. Some are protozoa, but the chief plant consumers of the sea, and the main support of the carnivorous animals, are generally accounted to be the smaller crustacea and, among these, principally the copepods.

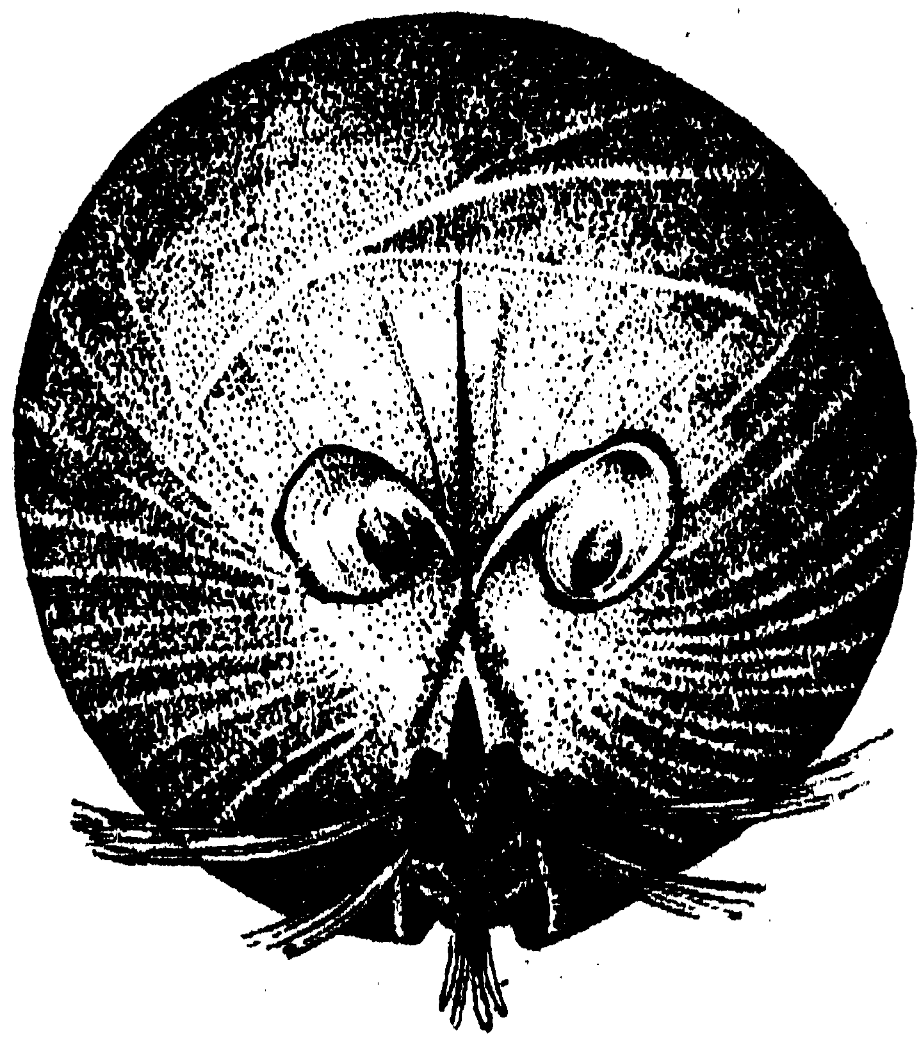
> We have already seen that the eucopepods are the chief intermediaries between the microorganisms of the ocean and the larger and higher marine animals; that they prey upon the protophytes and protozoa, and in their turn supply either directly or indirectly most of the food for the large inhabitants of the water; that most pelagic larvae feed upon them; that they are the food of the great pelagic banks of pteropods and heteropods (mollusks), of many coelenterates, of the young of most fishes, and of some of the most abundant and important adult fishes, like the herring, and that the sea-birds, the cetacea, and in fact almost all the larger pelagic animals, prey upon animals which in their turn prey upon copepods.[19]

There are other distinctive features of the marine communities as a whole. Comparison of fresh-water and marine plankton reveals a far greater variety of animals in the latter. In the first place, a most important element of the marine plankton is what is called *meroplankton,* comprising the larvae of organisms that spend only part of their lives in the plankton. Such are the young of starfishes and sea urchins, of worms, mollusks, crabs and sedentary ascidians. On the other hand, animal meroplankters constitute a very insignificant part of the communities of fresh-water plankton. There are also in the sea a great number of *holoplankters* (animals living exclusively in the plankton) of groups not represented in the plankton of fresh waters. Among such are free-swimming

[19] Brooks, p. 161.

mollusks (pteropods and heteropods), worms and free-living tunicates. The paucity in variety, not in quantity, of fresh-water plankton animals—protozoa, rotifers, crustacea of three groups, and little else—offers a striking contrast.

A brief and very general review of the distribution of animals of the several phyla, with respect to fresh water, the sea and the land may be illuminating. To begin with the simplest forms, no sharp distinction can be made between the protozoa and the flagellated protophytes such as the coccolithophores and dinoflagellates to which references have previously been made. With respect to protozoa proper, the casual collector will undoubtedly make acquaintance with a much greater diversity of types of protozoa in fresh water, but the unicellular animals play an equal and probably a much greater part in the bionomics of the sea than in that of fresh waters. The extensive areas of Globigerina Ooze, covering more than half the floor of the Atlantic, and the less extensive but still significant areas of radiolarian ooze testify to the vast abundance of both Foraminifera and Radiolaria, groups that are scarcely represented, the Radiolaria not at all, in fresh waters. Again, one could hardly encounter in fresh waters any phenomenon comparable to the occasional enormous populations of the cystoflagellates, *Pyrocystis noctiluca* and *Noctiluca miliaris,* flagellate protozoa of very large size, up to 1 mm in diameter for Noctiluca, and characterized by the capacity for luminescence. In certain coastal waters, as at Beaufort, N. C., Noctiluca may at times occur with such density of population that any moving body in the water is brilliantly outlined in light by the flashes of the protozoa with which all parts of its body are making continuous contact. More impressive testimony to the capacity of some organisms for multiplication or for concentration in the sea under conditions not fully understood is that of Allen (1937), who found *Noctiluca scintillans* in a concentration of 3 million to a liter in sea water as *dipped* from the surface in the Gulf of California. Since this well-named "Scintillating Night Light" is macroscopic rather than microscopic in size (it may attain a diameter of one millimeter) 3 million of them in one million cubic millimeters would leave little room for water. The cystoflagellates are almost entirely marine, but some other groups of flagellates, the ciliates and tentaculates, are more numerous in fresh water. Nevertheless,



GIANT OSTRACOD
Gigantocypris agassizii G. W. MÜLLER.
(FROM MURRAY AND HJORT AFTER MÜLLER.)

Clemens (1935) has found great patches of water near Nanaimo, B. C., colored "crimson red" with a "pure culture" of a ciliate protozoan, *Mesodinium rubrum* Lohmann.

The sponges and the coelenterates each comprise a great number of species with notable diversity of form and habit, and nearly all species of both groups are found only in the sea. Likewise, the polyzoa or moss animalicules are mostly marine; only a few species of each of these phyla have invaded fresh water. Nemerteans, or ribbon worms (with an excep-

BLUE WHALE ON FLENSING PLATFORM
AT WHALING STATION IN SOUTH SEAS. FROM "DISCOVERY" REPORTS.

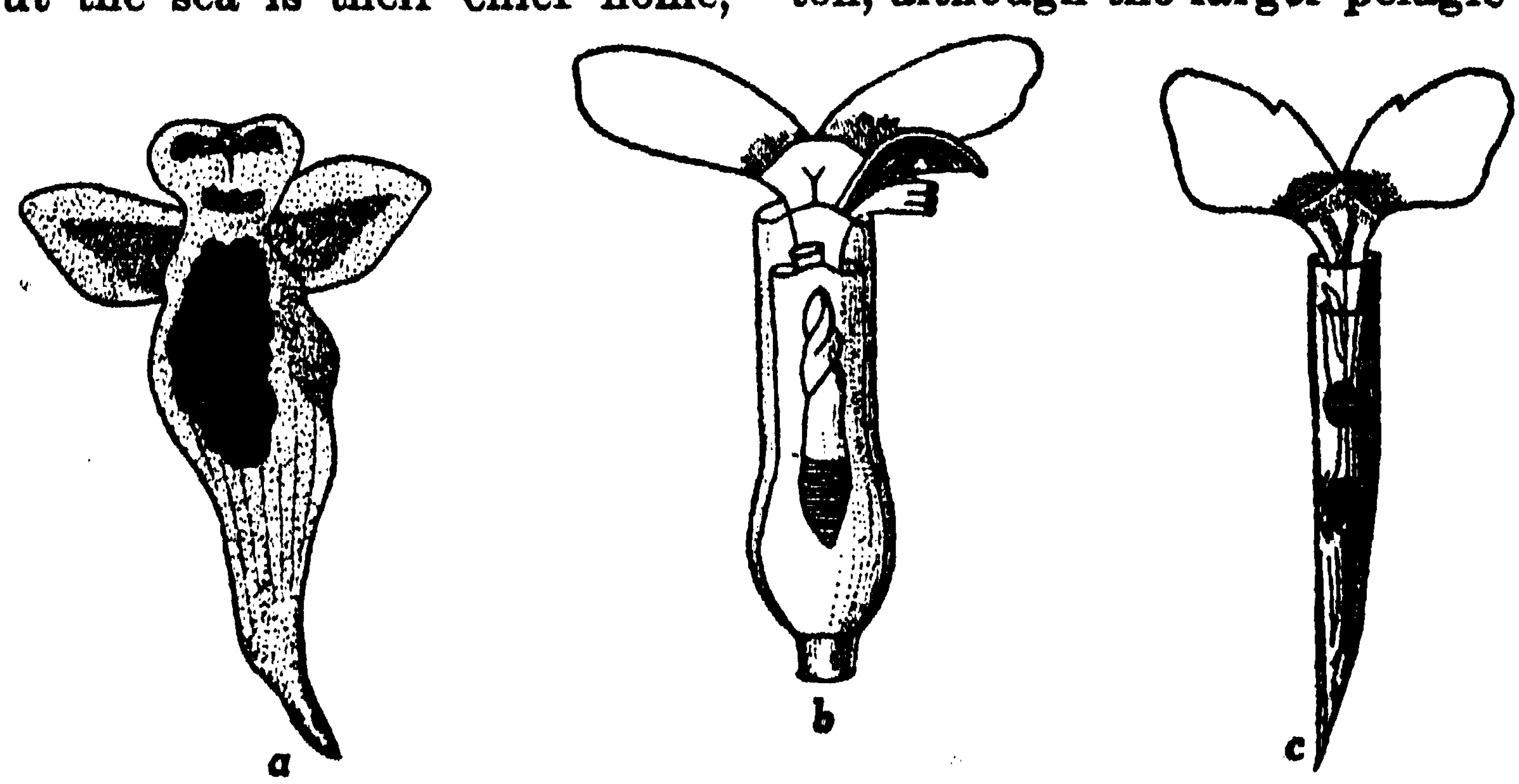
tion or two), Echinoderms (starfishes, etc.) and Brachiopods are exclusively marine while, on the other hand, rotifers, with a few exceptions, and Gastrotrichs are restricted to fresh waters. Flat worms and round worms, respectively, are much more generally distributed, occurring in salt and fresh waters, and as parasites in fresh-water and terrestrial animals. Among the Annelids there are two small classes that are exclusively marine; a third class, the Chaetopods, which embraces the worms proper, are widely represented both in sea and in fresh water, but in the main those of the sea belong to one subclass and those of fresh water to another; the leeches, constituting the fourth class, are almost exclusively inhabitants of fresh water, although a few are marine or terrestrial.

The mollusks embrace two classes that are exclusively marine, the Scaphopods (tooth shells) and the Cephalopods (squid, octopus, nautilus); those of a third class, the Pelecypods or bivalves, occur broadly in fresh waters and in all seas, but doubtless the greater number of species are marine. The Gastropods, including snails and conchs, are also more abundantly represented in salt than in fresh water, but two very distinct types of snails have invaded the fresh waters and there developed a considerable diversity of species. One of these groups, comprising the pulmonate snails, has entered the fresh waters indirectly, by way of the land, and its members are but imperfectly adapted to life in water. The most prominent point of contrast between the molluscan faunas of fresh waters and oceans is found in the entire lack in the former of the free-swimming mollusks that constitute so significant a part of the oceanic fauna. Reference is made to the Heteropods and Pteropods (among the gastropods), the latter as "flying snails" or "delicate shield-shaped shells driven along by a pair of flapping fleshy wings"

(Beebe), frequently so extraordinarily numerous in the plankton as to merit the name of "whale-feed"—and to the Cephalopods, represented by the great schools of squid, the floating argonauts and other well-known types. All fresh-water mollusks, in contrast, are benthonic—creepers, clingers or burrowers.

The several classes of arthropods divide themselves conveniently into two groups, comprising, respectively, those that breathe by means of gills, the Crustacea, and those that have the tracheal system of respiration, chiefly myriapods, insects and arachnids. The several classes of the tracheates are, of course, primarily terrestrial, but a number of insects and arachnids have invaded the fresh waters and a *very few* have returned to the ocean. The Crustacea are extensively represented both in the sea and in fresh waters, but the barnacles are exclusively marine, and the ostracods and the larger Crustacea (crabs, lobsters, shrimps, etc.) chiefly so, with few genera in fresh waters. The Branchiopods (fairy-shrimp, cladocera, etc.), on the other hand, are principally inhabitants of fresh waters. The copepods are much more equitably distributed between the two kinds of waters, but the sea is their chief home, and there they are paramount among the small animals. "It is an undoubted fact," says Russell (1934, p. 2025) "that the Copepods are the most numerous components of the animal plankton community." Neither on land nor in fresh water can there be found a single small group so generally dominant as are the four or five species of copepods that account for such a large part of the oceanic plankton. For a comparable condition we should perhaps have to take a single lake or a single habitat on land offering uniformity in chemical conditions.

We have to pass over the diversity of larger crustacea which occur in profusion in the ocean but are scantily represented by crayfish, amphipods, isopods and a few shrimp in fresh waters or by isopods and crabs of very limited distribution on land. Most of the larger crustacea are benthonic, but their larvae may be very prominent components of the plankton, and some species are pelagic at all stages. I have seen great areas of the Pacific Ocean, off the coast of Peru, blood-red with the shrimp, *Munida cokeri* Rathbun, about two inches in length. Unlike the mollusks, the free-swimming crustacea are well represented in fresh-water plankton, although the larger pelagic crustacea



FREE SWIMMING PTEROPOD MOLLUSKS

(a) *Clione limacina* PHIPPS.

(b) *Cuvierina columnella* RANG.

(c) *Creseis virgula* RANG.

("A" FROM MURRAY AND HJORT, AFTER VANHÖFFEN; "B" AND "C" FROM CAMBRIDGE NATURAL HISTORY AFTER SOULEYET.)

have no counterparts in the limnetic communities.

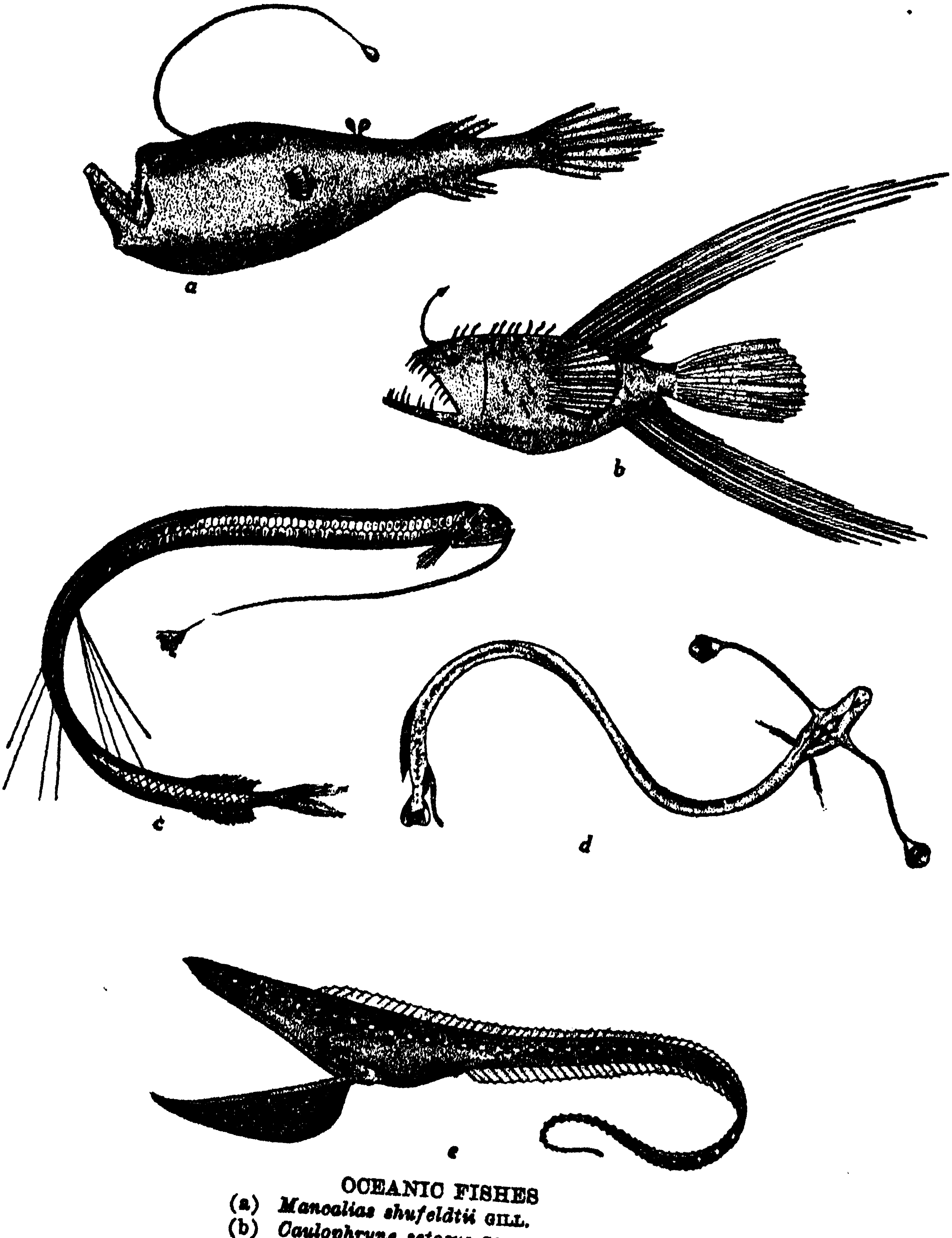
When we come to the Chordates, we find first a group of subphyla including primitive or degenerate types—Balanoglossus, the Amphioxus and the Tunicates—which are restricted to the sea, and another subphylum that comprises the six or seven classes of Vertebrates. The lowest of these classes, the Cyclostomes, are doubtless primarily of marine habit, but some species ascend the rivers and one or two remain in fresh water all the time. The fishes are, of course, widely distributed in fresh and salt water, but within this class the lower groups, the Elasmobranchs and Holocephs, are exclusively marine. There are, on the other hand, some small subclasses, the Dipnoi and the Crossopterygians, that are restricted to fresh water. The next higher class, the Amphibia, bridges the gap between land and water, but, strangely enough, is entirely unrepresented in the sea. The remaining three classes, reptiles, birds and mammals, are all terrestrial except in so far as a few species of each class have become secondarily adapted to life in water, salt or fresh.

Allusion at least should be made to animals that constitute links between land and fresh water and the ocean. Such are the seals, sea lions and many birds of aquatic or semi-aquatic habit, whose lives are divided between sea and land or atmosphere. There are also anadromous fishes, such as the shad and salmon, which feed and grow to maturity in the sea but ascend into fresh water for purposes of propagation and the location of nurseries for their young; and, on the other side, the catadromous eels which come to maturity during a period of twenty years or less in fresh water, but migrate far out into the depths of the sea to deposit eggs which develop into translucent larvae that will rise toward the surface and, in the course of a couple of years, wend their way back into the fresh waters of the continent from which their parents emigrated. A few fish are amphibious, passing freely from sea to land and back again.

From this brief review we glean one thought at least: that the diversity in basic types of living animals is much greater in the ocean than in fresh water or on land, but that, on the other hand, the number of terrestrial species is much greater owing entirely to the remarkable evolutionary success of the tracheate types—insects and arachnids. Furthermore, the more highly specialized and efficient animals have developed without the sea: fishes represent the highest form of marine life—by the systematic zoologists' system of grading. The number of species of all animals is smaller within the sea than without, but there is in the ocean a predominance of the more primitive types of animals and of those types that constitute possible links between the several phyla. In a way we may look upon the seas as representing a living museum of biological antiquities, or, it might better be said, as comprising the chief repository of the early archives of our family history.

Richness of Life in the Ocean

It is too early yet to make any strict appraisal of the quantity of life in the sea. As has been said, Krogh regards the sea as less productive than the land. Generally speaking, coastal regions and the Continental Shelf are probably more richly inhabited than the remote regions of the bottom of the sea, but, so far as we now know, there are no completely azoic depths. Similarly, as regards plankton, there appear to be no azoic levels, free-swimming organisms being encountered from the surface to the greatest depths explored. In November, 1934, Beebe descended in his bathysphere to a depth of more than 800 meters (2,500 to



OCEANIC FISHES
(a) *Mancalias shufeldtii* GILL.
(b) *Caulophryne setosus* GOODE AND BEAN.
(c) *Macrostomias longibarbatus* BRAUER.
(d) *Stylophthalmus sp.* BRAUER (young).
(e) *Gastrostomus bairdii* GILL AND RYDER.
("C" AND "D" AFTER CHUN; OTHERS AFTER GOODE AND BEAN.)

3,000 feet). He said: "The remarkable abundance of animal life that came within our exceedingly limited visual area at almost all depths was wholly unexpected" (Beebe, 1934). Some organisms may be restricted to particular levels and even incapable of maintaining life at other levels, while others engage in notable vertical migrations, moving from great depths to superficial waters and back again. There are occasions and places where, under the influence of favorable conditions of mineral substances in solution, of other elements of food supply and of temperature, luxuriance of plant and animal life may occur to give rise to such phenomena as the great "Red Seas" of dinoflagellate protozoa (or algae) previously mentioned, or to the even more conspicuous aggregations of shrimp, of copepods or of pteropods (free-swimming mollusks) so well known to whale fishermen as pastures of "whale feed" and, accordingly, as likely indicators of the presence of the eagerly desired whalebone whales.

It is possibly correlated with the great range of movement offered by the sea as well as with the relatively high buoyancy of the saline waters that the largest of all animals, whales, occur in the sea. The whalebone whales, indeed, give us perhaps the most vivid suggestion of the capacity of plant and animal plankton of the sea to support higher animals. Feeding as they do upon the very small but macroscopic animals of the plankton, such as the copepods and pteropods which they filter out from the water, they "represent the maximum energetic efficiency attained in the ocean." Their rate of growth, says Krogh, is "unparalleled in the animal kingdom." A blue whale 7 m. long at birth and weighing 2,000 kg., he says, becomes sexually mature at 2 years, with a length of 23 m. and a weight of 60,000 to 80,000 kg. An increment in weight of body of more than 30 tons in one year manufactured from the strainings of the open sea, is indeed an impressive demonstration of intensified metabolism!

A notable phenomena of distribution is the richness of life in the cold and turbid seas of the north, when these are compared with the warm and translucent waters of the tropics where conditions of temperature and light might be expected to support the richest fauna and flora. It should be remarked, however, that waters which are geographically within the tropics but which are not tropical in conditions of temperature, such as those in the Humboldt Current off the west coast of Peru, may rival the waters of higher latitudes in luxuriance of animal and plant life. The warm and light waters of truly "tropical" regions may hold less oxygen and, remaining at the surface, be drained of their nutrient materials which are not replaced by ascending currents from the depths. "Pure blue is the color of desolation of the high seas" (Schutt, quoted by Johnstone).

Thus the colder seas are richer in life than the warmer ones; or, at the very least, the amount of life in polar seas is not less than in the tropics. We know that intense sunlight and high temperature are favorable to plant life and so these results are at first sight astonishing ones. "One stands," says Kjellman, "as before an insoluble problem when he makes a haul with a tow-net in the Arctic and obtains abundant and strong vegetation, and this at a time when the sea is covered with ice, the temperature is extremely low, and nocturnal gloom predominates even at noon."[20]

[20] Johnstone, 1908, p. 205.

THE WESTERN BIOTA

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It is interesting to contemplate the life about us, and ask whence it came and how it came to be what it is. A complete answer to such questions is of course impossible, and were it available, it would pass our understanding. Yet the larger features of the history and some of its details may well detain us, and suggest lines of inquiry which will be fruitful of interesting results. In Colorado we find some of the earliest known traces of vertebrate animals, and through the many millions of years represented by the Mesozoic strata, gigantic dinosaurs and other strange creatures inhabited the western country. Although many fossils have been found, the record is very imperfect, as shown by the fact that several successive Cretaceous strata contain wholly diverse species, the unrecorded time interval between them having been sufficient for the evolution of an entirely new set. In those days, the country east and west of the mountains was occupied by a shallow sea, filled with life of many kinds, including fishes of gigantic size. It is probable that the origin of many of the modern groups of fishes may have been in this sea, while on the land the plants and invertebrates were already assuming what we should call a modern aspect. The attention of paleontologists has been so generally directed to mammalian evolution, which has been extraordinarily rapid, that they have not usually appreciated the vast antiquity of the groups of plants and lower animals, even many genera coming down to us from Mesozoic times.

This very ancient life, so far as represented by fossils in our region, is not closely connected with the modern biota. There has been time enough for its descendants to spread all over the earth, so far as they were able to survive and circumstances permitted, and it is doubtful whether we can ascribe any particular features of our fauna and flora to the fact that certain groups flourished in western America during Paleozoic and Mesozoic times. At what period, then, can we observe the origins of the present Rocky Mountain biota, occupying the territory where their descendants still live?

In the earlier part of the Tertiary, in the Paleocene and Eocene rocks, we find a great series of fossils, sufficiently numerous and diversified to give us a fair idea of the life of those times. It was a period of mountain-building, the dinosaurs had gone, and the mammals were rapidly developing, though still very different from those now living. But many of the plants belong to modern genera, and all of them have a modern aspect. The flora is strikingly diversified as compared with that of the Mesozoic, though the differences may no doubt be partly explained by more favorable conditions for preservation. The insects have a very modern aspect; the oldest known digger wasp, with its wings spread out and showing the pattern, would excite no surprise if collected alive in Colorado to-day. Certainly this fauna, especially as preserved in the Green River shales, contains many elements still more or less characteristic of western America, though by no means peculiar to it. Yet it also contains groups, such as the prettily marked moth-like fulgoroid Homoptera, which still abound in parts of the tropics, as India, but are unsuited to our present relatively cold climate. Lepidoptera seem to be very scarce, being represented by a couple of moths, one of them with the wings

banded just as in some living species. Dragonflies are fairly numerous, belonging to genera now extinct.

So far, it can not be said that we have positive evidence of the existence of ancestors of peculiarly western American life, unless we count such mammals as the Eohippus, considered to be a very early representative of the group including the modern horse, a group which seems to have been originally American, spreading during Tertiary times into the continents of the Eastern hemisphere. There is, however, one apparently genuine example in the genus of snails named by Pilsbry Oreohelix, or the mountain snail. Characteristic Oreohelix occur low down in the western Tertiary, and to this day the genus is dominant in the Rocky Mountain region and confined to western America. There is no reason to suppose that during the many millions of years of its existence, it ever extended into the Atlantic states, to Central or South America or into any part of the Old World. Contemporaneous with Oreohelix in the West in Eocene times were several kinds of land snails which have now disappeared from this region or are wholly extinct. Some of these are so peculiar that it has been proposed to recognize for them a distinct family, the Grangerellidae. Some important elements in the present snail fauna had perhaps not yet evolved, or it may have been a matter of chance that they were not preserved. The very distinct genus Ashmunella, with numerous species, lives in New Mexico and Arizona and has not yet been found in Colorado. Its oldest remains are Pleistocene or Holocene, yet it would occasion no surprise if it were to be found rather low down in the Tertiary.

Various writers have constructed bridges across the great oceans, in order to explain the distribution of life. It has not been sufficiently realized that the duration of life of a family of animals or plants, or even genus, and often for a species, has been ample to enable it to spread over the entire globe, supposing conditions to be favorable. Such spread might be excessively slow, yet it would suffice. It has also been argued that specific characters are not usually adaptive, because the characters by which we recognize species often appear not to affect survival. It is not necessary to show in detail that this is a mistake. Consider, for instance, the highly peculiar and very distinct Pacific Coast flora, with its accompanying fauna. Why do we not find this biota spreading eastward across the country? Obviously, because it is limited to those regions in which it can thrive. Its characters are highly adaptive, that is, suited to its normal environment.

Oceans and deserts or semi-deserts have been important limiting factors. In the Western flora we now find a long series of genera which do not belong to the region, but have come in as weeds, mostly from Europe. Some flourish exceedingly, others remain rather local or scarce. Insects show the same phenomena, and the wide distribution of the European sparrow is a case in point. These examples teach us that the great oceans are very ancient and that much time has elapsed since it was possible for the temperate biota as a whole to pass from one side of the world to the other. The circumpolar biota, which we find in our mountains and to the north, consists of species which could endure the conditions of the northern route.

The dry plains or deserts are not usually such complete barriers. It is difficult to estimate the barrier due to the dry region east of the Rocky Mountains, because about the hundredth meridian the climate changes, and it is probable that if the mountains were immediately adjacent, the Eastern biota would be hindered from spreading into them. But some recent examples prove to be exceptions to any such rule. It was supposed that the bean beetle, Epilachna, was confined to the West because of its inability

to endure other climates. But, in recent years, it has spread right across the country and has become a serious pest in the Southern States. Is it possible that it produced a physiological mutation, able to endure the more humid climate, or is it exactly the same beetle which had to wait until accidentally transported by man, probably on automobiles? Another similar case is that of the cecropia moth, so well known to every one in the Eastern states. In the Rocky Mountains we have a related species, *Samia gloveri*, strikingly different in coloration. But within the last decade or so, the cecropia has crossed the plains, north and south, in a vast army, and is now common in the Rocky Mountains. Wherever it has gone, it seems to have supplanted gloveri. In the Eastern states is a peculiar black bee, with two light spots on its tail. It is called *Melissodes bimaculata*. In quite recent years it has appeared in the country about Boulder, Colorado, and is now rather common. It is so different from the other bees of the region that it could not have been there previously, unobserved.

Northward in Saskatchewan and Alberta, the barrier is less distinct, and there is in fact a mingling of species which we have thought of as eastern and western. Furthermore, in my studies of the bees, I have found that in several cases there are closely allied but distinct species southward, represented in Alberta by forms which are not identical with either, but clearly intermediate.

There are some forms of life which are particularly instructive in regard to past conditions. Such are the fish, the mollusks, the millipedes and the earthworms. In Colorado, the two sides of the Rocky Mountains differ almost entirely in their fish fauna, not only as to species, but as to genera. The abundant small Cyprinidae or minnows of the Mississippi basin and the Eastern states generally have remained in that territory, and do not occupy the rivers and streams of the Pacific slope. This in itself is testimony to the long duration of the mountain barrier.

The mollusks, millipedes and earthworms illustrate other phenomena. Where the country has been glaciated, the native earthworms have disappeared, and there are none in Colorado, except such small forms as the Enchytraeidae. But there is a broad zone, perhaps best represented in Oregon, where the country has remained free from ice and yet moist enough to support a good earthworm fauna. Here are rather numerous endemic species of these animals. In the case of the land mollusks and the millipedes, we have numerous local species or races, isolated in different ranges which have sufficient moisture for their survival. There is evidence here of the progressive desiccation of the country, but the highly adapted desert biota proves that desert conditions existed from very remote times. The slug Anadenulus in the Cuyamaca Mountains is one of the most remarkable examples. A very distinct genus, it is represented only by a single collection made years ago by Hemphill in these mountains near San Diego. It has not been seen since, and is possibly now extinct. In Southern California, Arizona and New Mexico, there are very numerous species or races of Helicoid land snails, each confined to a very limited area. Thus it happens that in looking at a list of the snails of Southern California, one is astonished at the number of species, yet on going out into the field one is equally surprised at the scarcity of the fauna. Last spring, I visited Jacumba, on the southern border of San Diego County, right on the Mexican line. I thought I should find a snail fauna there, but although there is a creek which had brought down a great quantity of debris, not a single shell could be found. In almost any other country there would have been several or many species of small snail shells. The apparent paradox is of course explained by the

unsuitability of most of the region for snails, and the consequent isolation and differentiation of colonies in the various favorable localities. The millipedes tell just the same story.

It results from all this that the whole region is of extraordinary interest to the naturalist, who may expect to find isolated, relict species, sometimes distinct genera, at many points. This survival of ancient types is not confined to small things; it is exemplified by the species of Sequoia and the California condor, as well as various forms known to have died out in very recent geological times. Thus the Western Pleistocene, with its fossils, is of prime importance in connection with the study of existing life.

Here in Colorado we have an animal, the so-called antelope, which represents the last remnant of a remarkable and once highly diversified group, as shown in detail by Frick in a volume lately published by the American Museum of Natural History. It is widely spread, north and south, but is endemic on the Western Plains.

It is interesting to examine the various genera, and ask why some are represented by single species and others by a great multitude. Are the monotypic genera nearly always isolated remnants of a once diversified group? Why is it that certain genera are very rich in species at one time or place and poor at other times or places? Among the bees, the common genus Andrena very possibly has a thousand distinct species in the United States, and it may be that this is an under estimate. New ones are found every year, and large areas have yet to be searched for them. These bees are many of them oligotropic, that is, confined in their visits to particular types of flowers, and the diversity of the flora is connected with the diversity among the bees. But another genus, Heriades, has only a few species in North America to-day, though they were numerous in Miocene times, as shown by the fossils in the Florissant shales. They are still very numerous in the fauna of South Africa.

Work on the large genera of animals or plants is exceptionally difficult, on account of the mass of material to be dealt with, and the necessity for forming critical judgments. But it is this type of work which will help us to understand the nature and causes of the evolutionary process.

What are the prospects for work on the Western Biota in the coming years? Can we, of the older generation, contemplate our unfinished business with the assurance that a new generation, profiting from our successes, learning from our mistakes, will carry the subject to a point far beyond our present vision? We hope it may be so; we feel quite sure that, sooner or later, it will be so, but we see certain obstacles in the way. American life, whether in or out of our large institutions, is not as a rule favorable for continuous and ardent intellectual labors. There are only a few places where large collections of specimens or books can be consulted. And when the work has been done, there are few opportunities for its publication. Perhaps we should marvel that it can be published at all, when most of it is read, at the present time, by only a handful of people, and really exists primarily for posterity. Very frequently, to say the least, those doing the work have little appreciation of its broader significance, and in the nature of things it is impossible to foresee what structure of knowledge will be eventually built out of the facts now coming to light. It would doubtless help matters if there could be published, in readable form and well illustrated, a series of little manuals showing the methods of study and the broader significance of the work. Such books might interest many who would be repelled by the severely technical papers of specialists.

WHY DO INSECTS BECOME PESTS?

By Dr. E. PORTER FELT
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THE change from a comparatively harmless insect to a dangerous enemy of man or of material valued by him is to be expected where there is an abundance of suitable food and little or nothing in the way of natural checks.

It will help to clarify the situation if we remember that there is such a thing as the "balance of nature." There is in the world an immense number of insects and a long series of plants, each occupying a certain position and competing with other forms for the privilege of living. A great reduction in available food means a corresponding limitation in the numbers of the insect. The irregular cycles of injury of the apple tent caterpillar are due to the relative abundance of natural enemies. The wholesale killing of the caterpillars is followed by a great reduction in the numbers of the natural enemies, and these in turn increase as the caterpillars become more numerous. This is only one of many fluctuations in insect life. It illustrates what is going on all about us.

The development and prevalence of insect pests in America is an interesting story, especially as the one creature which has done the most to bring about such changes, namely, man, is the one complaining loudly because of the resultant damage to valued animals, plants and human health. It is well known that apple-tree insects are much more numerous, unless controlled, in both numbers and species in extensive apple-growing sections than elsewhere, hence the urgent need in large orchards for repeated sprayings or other repressive measures. The same thing can be seen in the extensive grape-growing sections of western New York. These hundreds of acres of vineyards offer unexampled opportunities to insects which feed upon grapes and they have not been slow to take advantage of the situation. A similar condition is developing in relation to shade trees and the insects which live upon them. In the early days of this country when communities were small and village trees few and widely scattered, there was little trouble from insect pests. The extensive plantings of elms in thickly settled areas and the numerous artificial shelters, especially belfries and open sheds, have provided ideal conditions for the wintering of elm leaf beetles near an abundance of acceptable food. It is not surprising that these insects have taken advantage of their opportunities, especially as they have been comparatively free from attacks by parasites or other natural enemies.

It is well to note in passing that a large proportion of our more serious insect pests of farm, orchard or shade trees are introductions by human agencies. Over one half of such pests have come from abroad. This has more than a passing significance, since these undesirable immigrants from other countries have by no means ceased to find their way to America. In spite of rigid quarantine restrictions of the past twenty-five years, other insects will come and take advantage of the exceptional opportunities in the western world.

Back in 1779 Hessian troops landed on Long Island, and it is the common belief that the very destructive Hessian fly was brought into the country with straw used for bedding the horses. This tiny pest found in the wheat fields of America conditions entirely to its liking and proceeded to lay a tax on American agriculture running into millions. Experience showed that certain wheats

were more resistant than others, though many farmers preferred to grow the less resistant varieties because of the larger yields and more desirable milling qualities. A hundred years after the appearance of this insect in America the more susceptible fields of wheat were occasionally blasted or destroyed. It was not until early in this century that the possibility of avoiding such catastrophic losses by seeding at the proper time was demonstrated. The insect itself is a fragile fly less than one eighth of an inch long. It travels readily with the air currents and is so prolific that millions may drift into and destroy extensive fields if the wheat plants are in a susceptible stage. The secret of success is to avoid a combination of millions of flies and tender wheat.

The fruit growers of eastern North America were much disturbed in the early 1890's when the San Jose scale was found killing orchard trees. It was so destructive that in the judgment of many progressive horticulturists apple growing as an industry was threatened. This pest was found on the Pacific Coast in 1880. It is now regarded as having originated in the Far East. Its distribution over the country was through the shipment of infested nursery stock with local distribution by both birds and wind currents. It is possible that carriage by birds was much more extended than was at first supposed. In recent years an infestation of the golden oak scale, another introduced pest, was found at South Kent, Connecticut, miles from a main thoroughfare or railroad and widely distant from recently transplanted oaks. It is probable that the young crawling scales were transported on the feet of one of the larger birds; a crow or a hawk might easily have carried the young scale insects for a number of miles. Possibly the same is true of the San Jose scale. It is interesting to note that after some twenty years in the East this wide-spread, destructive scale insect was being controlled here and there by minute parasitic insects. These were forms which previously existed in small numbers on relatively scarce, native scale insects and later took advantage of the great abundance of the San Jose scale and in time brought about what might be considered a normal balance. The scale insect throve immensely at first at the expense of its numerous tree hosts, only in turn to provide abundant provender for a, humanly speaking, beneficial parasite. Such is the way nature works.

Man has disturbed the balance of nature by planting large areas to single crops. These proved attractive to introduced pests. They also provide admirable conditions for native insects. One of the most striking cases is that of the Colorado potato beetle. Back in 1824 it was discovered feeding upon the worthless Buffalo burr or sand burr on the eastern slopes of the Rocky Mountains. Neither the insect or the plant upon which it fed was then of any importance to man. The Buffalo burr is related to the so-called Irish potato and in the late 1850's or early '60's settlers began growing the potato in that region, unthinkingly bringing to this hitherto insignificant and unimportant beetle a plant much more satisfactory as an article of diet. The insect multiplied greatly, worked eastward at the rate of about eighty-five miles a year and reached the Atlantic Coast in 1874. Here again man provided conditions favorable to the development of the pest, and in the early days of the invasion the farmer was well-nigh helpless, since he had not learned to use Paris green and was forced to depend upon hand collecting for whatever protection could be secured. This beetle, though occasionally troublesome now, is by no means the pest that it was fifty years ago. A number of natural enemies native to the invaded area have learned to prey upon the potato beetle and in many cases have reduced its numbers to such an extent that it may be

regarded as only another insect with somewhat injurious habits.

A similar story might be related of the Mexican bean beetle, which for three quarters of a century restricted its operations to the bean fields of Colorado and southward. In 1920 it appeared in northern Alabama and in 1929 was found for the first time in New England. There is evidence to support the belief that this insect was distributed to a considerable extent by wind drift. The great abundance and destructiveness of the Mexican bean beetle in the eastern states is due to the large areas devoted to beans and the comparative absence of natural enemies.

The cotton boll weevil is another insect from the Southwest. Its original home was in Mexico or central America, and one variety is known to feed on wild cotton in Arizona. It appeared in south Texas in 1892 and has gradually spread northward and eastward until it was found in every section where cotton can be grown, the annual spread of earlier years averaging about sixty miles. There is such a close limitation of the boll weevil to cotton that some years ago it was proposed to exterminate the pest in the United States by prohibiting the growing of cotton in a little over one half of the infested area for a time and then, allowing the planting of the cotton in that section, apply the same prohibitions to the remaining area, including a sufficient overlap to eliminate the possibility of spread from one area to the other. Theoretically it was possible. The boll weevil is still with us.

There are similar records in relation to insects attacking shade and forest trees. The gypsy moth, a serious and general pest of shade and forest trees in the northern United States, was brought into this country about 1868 in the hopes that a hardy cross with the silkworm could be produced and a new industry developed. It escaped, multiplied tremendously and in the early '90's the state of Massachusetts attempted to exterminate the insect. This was abandoned, and federal and state agencies joined in control work designed especially to limit spread. It was found that although the females do not fly, the young caterpillars are taken up by wind currents and carried twenty miles or more, an explanation for the occurrence of disquieting woodland infestations. The gypsy moth is also spread by the transportation of egg masses, which may be attached to a considerable variety of objects, such as building stone, lumber and even freight cars, if they happen to be standing near infested trees during the egg-laying period. It is seventy years since this insect was brought to America. It is still a serious pest in localities where no efforts are made to control it. Federal and state agencies are cooperating in an attempt to hasten biological control by the introduction and propagation of natural enemies. These beneficial forms are rendering material service, and it is possible that in time this notorious pest will become relatively innocuous.

Agencies which aid the spread of insects are of great importance. Certain beetles, especially the Colorado potato beetle and cotton boll weevil, presumably have depended to a considerable extent upon their powers of flight in view of the moderate distances covered from year to year. The Mexican bean beetle appears to have been aided considerably by wind currents, and this is undoubtedly true of small moths with a wing spread of less than half an inch, such as the apple and thorn skeletonizer and the larch case bearer, both introduced and both rapidly distributed over the country, infestations being found in remote wooded areas. It is probable that wind currents aided materially in the spread of the introduced larch sawfly, an important tamarack pest of the northern United States and also of the more recently introduced European spruce sawfly, an insect found in widely separated points in New England and northern New York in 1935. It is comparatively easy for insects to be carried long distances by air

currents. Our balloon experiments in recent years have demonstrated that drifts at moderate elevations of thirty-five or forty miles an hour are by no means uncommon and under certain conditions there may be considerably higher velocities.

Introduced insects may become of great importance because of their ability to transmit or carry plant diseases. This is well illustrated in the history of the European elm bark beetle, discovered in this country in 1909 and at that time supposed to be an important factor in killing elms at Cambridge, Massachusetts. It is believed now that the beetles were secondary enemies and that their abundance was due to the trees being in a weakened condition. This borer is unable to maintain itself in numbers on vigorous trees. It has become of great importance since the discovery of the Dutch elm disease in the northeastern states in 1933 and the subsequent finding that this beetle is the principal carrier of the elm trouble in America. The disease produces conditions most favorable to the development of the bark beetle, and the beetle is the important carrier. It is a vicious circle which can be broken by the elimination of diseased trees or the destruction of trees or parts of trees presenting conditions favorable to the breeding of the beetle. The marked strides in the control of this deadly infection in the United States have been due to systematic and thorough work by federal and state agencies toward breaking up this deadly combination.

A word as to the insects which disseminate such deadly infections as yellow fever, malaria, plague and a number of other serious affections of mankind. Both the yellow fever mosquito and the malarial mosquito must obtain their respective infections from an individual before they can convey them to another. Where there is no human reservoir these mosquitoes would be relatively harmless and here again we have man-made conditions working to his own harm. It is true that fleas become infected by plague from rats, but on the other hand rats are associates, though unwelcome, of man and there is a definite relation between the environment of man and the occurrence of plague.

It is well known that introduced insects are most likely to be much more destructive shortly after they have become well established and less injurious thirty to fifty years later. The explanation is that natural enemies which habitually prey upon related forms discover the introduced species and in time exert appreciable control. The great majority of our native species are so well controlled by adverse conditions or natural enemies of one kind or another that they are practically harmless. The Federal Government and various state agencies are attempting to hasten nature's control by searching out and establishing in this country parasites or other natural enemies which prey upon various important pests such as the gypsy moth, the Japanese beetle and the European corn-borer. Some measure of success has been obtained. Ordinarily development of biological control requires years of work. It is using bugs to control bugs. It is fascinating and logical in spite of serious limitations. The exceedingly destructive cottony cushion scale of citrus fruits was stopped in the Southwest and later in other parts of the world by the introduction of an efficient Australian lady beetle. This was a lucky strike, possibly one in a million. Usually progress in this direction must be much slower.

One must conclude that man is but one organism in a most complicated biological whole and as such can not blame his troubles entirely on Providence. It is possible for him to modify surroundings so greatly as to largely control insect pests of plants and to eliminate to a considerable extent danger from disease-carrying species.

CONSERVATION OF GAME BIRDS

By Dr. GRAEME A. CANNING

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No man should be a hunter until he is first a naturalist, for he must appreciate the problems confronting the game birds to maintain their species. Game animals should include only those whose flesh is palatable and who, by virtue of their methods of reproduction, can maintain their race. They should be only those forms whose natural wariness, speed and habits make their capture test the best of man's abilities. Among this group have been listed swimming, wading, perching and walking birds. Members of these game species were once very plentiful, but this great natural resource is gradually diminishing and a few varieties have even become extinct so that the conservation of these native game birds has become a pressing national problem.

Through greed and ignorance much of the nation's wealth has been lost, and through the inefficient cutting of forest lands, native timber areas have been destroyed. Dust storms have blown away fertile top-soil of western plains, and the air in these regions remains heavy with dust. Floods have carried off rich humus, clogging the mouth of streams and making them unfit for fish. These evidences of man's thoughtlessness have all required national programs to aid in the readjustment of nature's balances and as man has tipped the balances of the physical world against himself, so also is he now blindly destroying the wild bird life he professes to love.

Obviously in order that a species maintain itself, its rate of reproduction must equal the rate of destruction. This procreative rate is effected by: (1) the breeding areas, (2) the number of matings and young hatched during a season, (3) the numbers of pairs of birds in a territory, (4) and lastly the climatical conditions. The effectiveness of destructive factors in the maintenance of game birds are dependent upon: (1) natural powers and habits of birds which help them escape death (2) the presence of cover to which they can escape, (3) the presence of parasites to which they may be subject, (4) the prevalence of enemies from which they have to escape, such as predatory animals and the hunter, and lastly (5) unfavorable weather such as heavy snows, which will often extract an appalling toll of wild life. Some of these factors man can control; others he can only modify; while some lie beyond his power.

In the bringing about of a greater production of birds, man has two means at his disposal: (1) the establishment of natural breeding areas and (2) the artificial propagation and raising of birds. Both methods have advantages, and wherever possible they should be carried out together.

In the selection of breeding areas, particular attention should be given to natural foods and to the cover present, essential in providing location for nests and for escape. When these two factors are suitable, the game will remain in the territory and increase even when little attempt is made to check the number of natural predators. Public grounds such as parks, forests or game preserves, set apart by the state or nation, are ideally adapted for this cheapest form of game conservation and restocking.

While the above method has the advantage, much can often be accomplished by artificial propagation. This is effective, however, only with those forms which readily adapt themselves to the presence of man and which feed upon grain. Birds, such as doves, which feed their young by regurgitation are not adapted

to mass breeding, because of the obvious difficulty of mass feeding. Ducks and grouse can best be raised under "semi-natural game farming" conditions where areas are fenced off and all predators destroyed so that the young can be turned loose early and forced to find their own food without the danger of being destroyed. Under these conditions the nests can also be located and periodically robbed of the eggs, thus forcing the game bird to lay additional eggs and taking full advantage of their high productivity. The eggs removed can be incubated and the young turned loose early in life.

Artificial propagation finds its greatest use in the handling of birds such as quail, turkey and pheasants. Some idea of the high efficiency of this method is obtained when it is recalled that a pair of quail will hatch a covey of 14 or 15 birds, of which, frequently, only ten or twelve reach maturity. Under artificial, forced conditions a hen may produce an average of 60 to 70 eggs; 74 per cent. of these can be hatched and 67 per cent. of the chicks of this number raised.

As the region becomes stocked the number of pairs in a territory will increase and accelerate the return to the full game population suitable to the area. Weather conditions should always be carefully studied, since they effect the hatch and thus determine the number of birds that can be killed during the hunting season without depleting the breeding stock. Cold, severe winters will reduce the number of breeding pairs of the next spring. An excessively rainy season will be followed by a poor hatch, as floods will destroy many nests and young birds. On the other hand, excessive dryness will prevent the hatching of many eggs, for proper humidity is an important factor.

Control breeding also has the advantage of permitting matings between desirable types. However, much thought must be given to establish what is the "desirable type," for the breeder must hold constantly in mind that the game bird's color, weight and size have been evolved and established through generations of natural selection operating in accordance with the impartial law of the survival of the fit. Man should hesitate before he attempts to change any of these factors in the bird's biology. Though certain forms seem to possess characteristics more desirable than native stock, the native possesses its features as a result of selection in the region to which it is endemic.

Man need not, therefore, bother himself by attempting to increase the birds' powers to escape or to resist parasites or inclement weather, for these powers they already possess. Man can far better apply his efforts in restoring their natural habitats. Modern farming has removed their natural cover, and the barb-wire fence has replaced the zigzagging rail fence behind which upland game formerly found refuge. Modern farming methods, with the removal of all natural protection, is undoubtedly one of the most important factors in the disappearance of game. A quail on the closely cut field stands out conspicuously against a bare sky-line and a widely spaced barb-wire fence affords it no protection from the predatory bird or mammal. Although in many regions the numbers of hawks and native fur-bearing animals have been decreased, this reduction has been augmented by an increase of the house cat and in some regions the fox. These carnivorous animals are relentless hunters, both in and out of season, and the cat, at least, multiplies its numbers under the protection of man.

The development of the modern shotgun has added a new problem with which game birds must contend. Yet, no hunter wants to see the extinction of any of these forms. To him the whistling of the ducks' wings heralded by their chuckling or quacking is cherished music. Is

there in nature a more beautiful sight than a flock of doves swooping with the wind and sailing close to the ground, suddenly rising fifty to a hundred feet, and then tumbling and zigzagging out of range of the hunters' gun? What can be more thrilling than watching your favorite dog, backed by the others, suddenly freeze on a point? Once experienced, can man forget the tenseness of those minutes just before a whirl of wings sends the plump, brown bodies of the quail up and away to the protecting thicket at a rate of forty miles per hour? What man, having experienced these, would ever wish to eliminate them? They are sounds that stir again in him the spirit of conquest that has made him what he is. They cause his whole system to vibrate again with the life that cities and underhanded methods of civilization are tending to destroy. Through hunting, the man and the naturalist gain a new and a greater appreciation of the life they love. Human ignorance is the real destroyer of our wild game.

THE DIFFERENTIAL TIME INTERVAL FOR REMARRIAGE OF WIDOWERS

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In the event of the death of the wife how long does the average man wait until he remarries? While there are no statistics available on this question, as far as the writer knows, nevertheless, for certain selected groups, the approximate interval between the death of the wife and the remarriage of the husband can be ascertained.

In "Who's Who in America" there is enough available data to make possible the building up of a fairly accurate picture for various selected business and professional groups. Every case in the above volume, where the date of the death of the first wife and the date of the second marriage is given, has been included in Table I, according to the various occupational groups.

The crude mode and the median show that most of the men in these selected groups who remarry do not wait very long. The average step up to the altar about two and one half years after the marital partner has died. While there are no startling differences between these groups, there are a few that select their mates in less time than that.

If the median be used, the clergy, with the exception of the scientists, get married more quickly than any of the others. One half of them are remarried within two years. This reflects the social pressure exerted upon the Protestant clergyman to secure a wife. She is a necessity in the manse and in many respects an ecclesiastical asset. In most of the denominations a wife is considered a prerequisite for the minister who is interested in establishing himself in the pastorate. Bachelors, generally speaking, are not wanted by the churches. Hence, the widowed clergyman has additional reasons for remarrying which men in most of the other professions do not have.

The scientists in the sample number 71. This, as in the case of the engineers, scarcely constitutes a large enough number to warrant framing conclusions. But if, as the arithmetic mean and the median indicate, the scientists do remarry more quickly than members of other groups how can this phenomenon be explained?

It is proverbially true that artists and writers are more given to love and romance than persons in most other voca-

TABLE I

LENGTH OF TIME ELAPSING BETWEEN DEATH OF FIRST WIFE AND REMARRIAGE OF WIDOWERS ACCORDING TO BUSINESS AND PROFESSIONAL GROUPS. BASED ON WHO'S WHO IN AMERICA, 1932–33.*

Interval (in years) between death of first wife and the second marriage	Business	Educators	Clergy	Lawyers	Public officials	Writers and artists	Engineers	Physicians and surgeons	Scientists	Total Group in "Who's Who in America"
1	27	39	45	11	13	32	16	8	13	226
2	37	51	67	28	27	32	11	23	25	322
3	46	47	35	18	19	15	11	11	10	220
4	21	26	20	15	14	17	6	6	7	141
5†	10	20	17	6	8	9	8	6	3	91
Total cases	202	246	230	111	109	146	67	71	71	1,333
Averages in Years:										
Crude Mode	3.5	2.5	2.5	2.5	2.5	2.0	1.5	2.5	2.5	2.5
Median	2.8	2.7	2.0	2.9	2.8	2.6	2.6	2.5	1.9	2.5
A. Mean	5.42	5.45	4.51	5.50	5.03	5.05	4.66	4.86	3.95	4.94

* Since it is not possible to secure the time interval between the death of the first wife and the remarriage in terms of months it is evident that the use of years is not an exact calculation. If the wife died in 1923, for example, and the widower remarried in 1925, the interval is recorded as two years. In reality it may have been nearer three than two or nearer one than two years. These variations probably offset each other when there is a sufficiently large number of cases. In calculating the crude mode the middle of the class interval in which the largest number of cases fell was used, and for the median the value was determined by interpolation into fractions of years. There seems to be no significant correlation between the age of the husband at the time of the death of the spouse and the amount of time which elapses before a second marriage.

† Only the first five-year intervals are given here.

tions. The crude mode indicates that a good proportion of them remarry within two years after the death of the first marital partner.

The statistical averages for the engineers are probably typical, though, as mentioned above, the sample (67) is too small for the purpose of drawing valid conclusions. The crude mode for this group is one and one half years. Their early remarriage is probably explained by the fact that traveling around from one location to another, away from friends and relatives, the natural inclination is to seek another wife shortly after the death of the first.

The business men, lawyers, educators, public officials and physicians and surgeons seem to be in about the same class, though the business men and the lawyers seem to take a little longer than the others. If this is generally true, there is no apparent reason for it.

Whether the men who are listed in "Who's Who in America" are, in their remarrying habits, typical of those engaged in their respective occupations and professions, may perhaps be open to question. But at least they would seem to be representative of the upper strata in the various vocations that are listed in this study.

THE RAW MATERIALS OF EVOLUTION

By THEODOSIUS DOBZHANSKY

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For nearly eighty years evolution has been one of the basic problems of biology. During this time, however, the problem itself has undergone a most significant change. Darwin and his immediate successors had to prove first and foremost that evolution has actually taken place in the history of the earth. In this they were signally successful: for several decades no informed person has doubted, although some uninformed ones occasionally did, that the organisms now living have descended from very different organisms that lived in the past. Granted that evolution remains a very probable theory, not a fact; there is no more reason to doubt the validity of this theory than there is, for example, the existence, rise and fall of the Roman Empire.

Our intellectual curiosity is not satisfied, however, with knowing merely that evolution has happened in history. It remains to be found out what are the mechanisms responsible for the evolutionary transformations of living matter. An analogy with human history may be illuminating here. Once the fact that civilizations have risen and fallen in the past is established, an historian proceeds to examine the chain of events that has taken place in every particular instance, with the aim of discovering the underlying causes of the phenomenon itself. Now, it is patent that although the history of some civilizations is known in some detail, nothing but guesses have been advanced to explain their fate. With respect to organic evolution the situation is uncomfortably similar. Evolution has been, no doubt, going on, and at least for some groups paleontologists are able to sketch its actual course. But the mechanics of evolutionary changes has proved so elusive that geneticists, on whom the study of this subject has devolved, merely begin to see dimly their way to the goal. The mechanics, the physiological rather than the historical aspects of evolution, is what occupies our attention now.

Fundamental Units of Heredity and Evolution

An exact study of any natural phenomenon is greatly aided by the introduction of generally agreed upon units of measurement. It is no secret that the progress of evolutionary studies has been hampered by the failure to define such units in this field. Since evolution is essentially a change in the hereditary endowment of the succeeding generations, the units of heredity are the only ones that are likely to prove useful as units of evolution. Now, by far the greatest achievement of genetics to date is the establishment of the fact that the hereditary materials transmitted from parents to offspring are composed of discrete particles known as genes. Another fact of importance is that genes have their physical abode in the microscopical cellular elements known as chromosomes. Each chromosome contains not only a definite set of genes, but the latter are arranged within the chromosome in a fixed linear order. The kind of genes an organism carries and the manner in which they are distributed in the chromosomes determine, together with the environment in which the organism develops, all the external and internal characteristics.

In general, genes are remarkably stable and are passed from generation to generation without change. The same stability must be ascribed to the chromosome

structure: the gene arrangement is transmitted from parents to offspring, close and remote. The permanence of the gene and chromosome structure insures heredity, and is, of course, the antithesis of evolution, which implies a change of these constants. Yet, from time to time genes undergo sudden alteration, technically known as mutations. A mutated gene also faithfully reproduces its like and is transmitted to the offspring of the mutant individual as long as another mutation in the same gene does not take place. Similarly, the gene arrangement in a chromosome may undergo sudden changes, analogous to gene mutations. An altered chromosome is passed to its offspring until a new alteration interrupts this process.

Gene mutations and chromosomal changes are the elementary evolutionary steps which have been observed in many animals and plants in carefully controlled laboratory experiments. As a working hypothesis, subject to proof or disproof by further studies, we may assume that genic and chromosomal changes are the fundamental units also of the evolutionary process enacted in nature. Is it possible that such changes have brought about the entire variety of living organism which exists on the earth?

"Natural" Mutations

In well-studied organisms, particularly in the vinegar fly Drosophila, hundreds and even thousands of mutations have been observed to occur in laboratories. The general (or, perhaps, a better word here would be "superficial") characteristics of the mutation process are now rather well known. Mutations affect all sorts of characters. In the Drosophila flies mutations differ from normal or wild representatives of their species in the coloration of the eyes or the body, size and shape of the wings, bristles, eyes, legs, in the structure of various internal organs, in physiological characteristics such as reactions of the fly to light and gravity. Important organs may be drastically modified or altogether absent in mutants; thus, mutants are known having no eyes, having reduplicated legs, two instead of one pair of wings, changed sexual parts, mouth organs, antennae, and the like. Mutations termed lethals destroy the fly at various stages of its development, from early embryo up to the adult stage, or produce pathological changes resembling tumors in one or the other part of the body. If no artificial means to reduce them, such as x-rays, are used, mutations are on the whole rare. Mutation rates in most individual genes are probably less than of the order 1:10,000 per generation. Most mutations are recessive to the normal or original condition, that is to say a fly carrying the mutated gene in one chromosome and its normal counterpart in the other chromosome is normal in appearance (every fly carries, of course, two chromosomes of each kind). Finally, mutations usually show various degrees of the reduction of the viability compared to the normal or wild fly and could hardly compete with the latter outdoors.

It is especially the last of the above properties of mutations that has caused a number of eminent biologists to doubt not only that mutations could possibly play a constructive rôle in evolution, but that they occur at all in the natural state. Indeed, if instead of investigating the Drosophila flies coming from laboratory culture bottles we examine a sample of flies caught wild, an impression of surprising uniformity is likely to be gained. To be sure, some mutations can occasionally be discovered among wild flies, but their frequency is, by and large, negligible.

A lasting credit is due to the Russian geneticist, Tschetwerikof (Chetverikov), who has demonstrated that the ostensible uniformity of wild populations of Drosophila is merely a deceiving appearance. Since most of the mutations are recessive, a fly carrying one mutated and one normal gene is not distinguishable from normal. It follows that an inspection of wild flies is quite insufficient to detect mutations that may be present in them.

In order to bring mutations to the surface, a special genetic technique must be devised to obtain flies carrying a given chromosome twice instead of once. Chetverikov and his co-workers have tested the offspring of 239 wild *Drosophila melanogaster* flies collected in a certain locality in Caucasus, and found that more than a half of them carried one or more mutations in their hereditary materials.

Mutations in Wild Populations of Drosophila pseudoobscura

The results of Chetverikov's work have been confirmed and extended by several investigators, among whom Dubinin in Russia and Sturtevant in America must be mentioned most prominently. In collaboration with Miss M. Queal, the present writer has secured similar data for wild populations of *Drosophila pseudoobscura* inhabiting certain mountain ranges in California and Nevada. Samples of the fly population were taken in eleven separate localities, the flies brought to the laboratory, and certain crosses arranged as a result of which individuals carrying the same wild chromosome twice are produced. The characteristics of such individuals are then compared with those of normal wild flies. Only one chromosome has been studied in these experiments, although the fly species in question possesses five pairs of chromosomes.

The flies collected outdoors were in every respect "normal" or "typical" representatives of their species. They were quite uniform in appearance, although some of them were, of course, larger or more robust than others. This variability is not inherited, being due to the influence of the external conditions in which the fly larvae develop (mainly an abundance or a scarcity of the food supply). Yet, despite the external uniformity, between 3 and 4 per cent. of the wild chromosomes proved to carry mutations provoking more or less striking visible changes in the structure of the flies. Some mutants change the normal red eye color to an orange or a purplish one, others cause spoon-shaped or notched wings, polished body surface, etc. Some of these mutations are probably identical with types having appeared previously in laboratories; others are new ones. However, unexpectedly large the frequency of these mutations may seem to us, it is far exceeded by the frequency of mutations that produce no noticeable change in the structures of the fly's body, but that cause instead a change in the viability of the insect.

No less than 11 per cent. of the wild chromosomes proved to carry recessive lethal mutations. As stated above, a lethal is a gene that causes death of the individual in which it is present in double dose. Lethals are known to be one of the most frequent types among the laboratory mutations, but one is somehow unprepared to see the wild populations too replete with these death-dealing hereditary changes. Between 3 and 4 per cent. of the wild chromosomes are infected with semi-lethals, which reduce the viability of their carriers more or less drastically, but still permit some of the flies to survive. Finally, very many of the wild chromosomes contain genes that produce slight, although perceptible, deteriorations of the viability. Exactly how large is the proportion of such chromosomes is not an easy matter to determine, but it is likely to exceed 50 per cent. A minority, possibly not more than 10 per cent., of chromosomes seem to be free from genes reducing the viability, and a very small minority appears to carry genes that are favorable, at least under the conditions in which the experiments have been carried out.

Aside from the genes producing visible external effects and those manifesting themselves in a modification of the viability of their carrier, wild populations possess a wealth of mutants of still other kinds. Among these, genes influencing the development rate of the fly seem to be very common. Although minor variations occur, the genetic conditions encountered in all eleven populations

studied proved to be essentially similar; all populations are infected with mutants to about the same extent. The situation found in our samples of the natural populations of the fly appears to be not an accident or an exceptional occurrence, but a typical state of affairs in a species propagating itself by cross-fertilization. It is justifiable to conclude that mutations are so frequent in nature that not only every individual but probably every chromosome carries one or more mutant genes. The reason why this fact has been overlooked for so long is, however, simple enough: mutations are concealed in the hereditary materials of the organism due to a majority of them being recessive.

Chromosomal Changes in Natural Populations

The time is not so remote when chromosomal alterations, especially the variations in the gene arrangement in the chromosomes, were considered rare phenomena. About ten years ago Muller did a great service to biology by showing that chromosomal alterations can be induced artificially by x-rays treatment. Now we are in possession of data that show that these once genetic oddities are not at all rare in wild populations. An example dealing with the already mentioned fly, *Drosophila pseudoobscura,* will suffice. Strains of this fly were secured from various parts of its geographic range, extending from British Columbia to Mexico and from the Pacific to Texas. One of its chromosomes, namely the Y-chromosome, proved to be variable in size and in shape; seven different types have been distinguished, each type being restricted to a definite part of the specific distribution area. Sturtevant and the writer have detected seventeen structural types in the third chromosome of the same fly, five in the second, two in the fourth, and four in the X-chromosome. Again, each type of chromosome structure is present only in flies inhabiting a certain region, although in many localities several types are mixed in the same population.

The Viability Paradox

It is clear from the foregoing discussion that an enormous supply of genetic variability, both in the gene and in the chromosome structure, is present in natural populations. This variability is comparable to that which is known to arise in carefully controlled experiments in genetic laboratories, and it is also similar in kind to the structural elements into which the differences between natural races and species can be resolved. Yet, a theory that would endeavor to assign equality to these three phenomena is confronted with an obstacle that may seem well-nigh insuperable. Indeed, most mutations obtained in the laboratory and found in wild populations are deleterious to the organism. In fact, many of them are lethal. It would seem, then, that the presence of such mutations in nature presages an eventual catastrophe to the organism rather than a progressive evolution. It is no idle phrase to say that the situation is an extremely challenging one. In the following paragraphs an attempt is made, however, to indicate one of the possible escapes from the apparent impasse.

The viability effects produced by a mutation or a chromosomal change are not a fixed or unchangeable quantity. On occasion the viability effects of a gene may be changed in the presence of other genes. Two mutations taken separately may produce decreases of the viability, but a combination of the same mutations may display any viability, from a very low one to normal. Moreover, a mutation which in a certain environment is deleterious may prove to be favorable in other environments. No better example of this situation can be demanded than that furnished by Banta and Wood: a mutation in a species of water fleas does not survive at a temperature that is optimal for the ancestral type, but the same mutant is viable at a higher temperature which is

unsuitable for the latter. Unless the properties of the genetic and the secular environments in which the viability effects of a given mutant are studied are known in detail, the results of the studies are ambiguous. All that we really know about mutations encountered in wild populations of Drosophila is that in the environment in which the flies have been kept in our experiments a large majority of the mutations are deleterious. There is no basis for the assertion that these mutations will be deleterious in every possible environment. This does not mean, of course, that an environment may be found in which every mutation will be favorable; one simply must refrain from making conclusions too fast.

Adaptation

It is axiomatic that the life of an individual or a species can endure only so long as a certain equilibrium between the organism and its environment is maintained. It is not axiomatic, but nevertheless true, that for most organisms the equilibrium is precariously unstable. One may be tempted to speculate that in an eternally constant environment all the survivors may become so ideally adjusted that the best of all possible worlds could at last emerge. This inference may justly be doubted, and in any case the question has no more than an academic interest, for in reality the environment is not constant, neither on the geological nor on the everyday scale. The organism must, therefore, either change itself in conformity with the demands of the new environments, or face extinction.

On the individual level the adaption is accomplished, within limits, with the aid of various physiological regulatory mechanisms. On the species level adaption involves a change in the genetic makeup, a succession of mutations, evolution. The crucial question is whether or not the living organisms can react purposefully to the demands of the environment, by producing those, and only those, mutations that are desirable in a given set of conditions. The whole sum of our knowledge argues in favor of a negative answer to the above question. To all appearances, mutations are random changes of the gene structure. Natural selection can pick out those mutations that are useful at a given time, but it can not prevent the concomitant origin of neutral and harmful ones.

A genetically uniform species may be in an advantageous position in a static environment, provided it has become adapted to it. But such a species will be threatened as soon as the environment changes, for it will be then devoid of the materials from which adaptations can be built. Conversely, a species possessing some genes that are deleterious in the present environment but advantageous in others may be better off in the long run. Here it must be kept in mind that these deleterious genes manifest themselves only seldom, when individuals having them in double dose are produced. Even if a majority of mutations are not useful in any circumstances, it may be desirable for a species to withstand their presence for the sake of a minority that may save its existence eventually.

Adaptation is not given to the organism as a gift. It must be purchased at a price, and the price is from our human standpoint, a revoltingly high one. However seldom the deleterious genes present in the species populations may manifest themselves, still some individuals in every generation succumb to their action. Paradoxically enough, it is the loss of these individuals that guards the species as a whole from extinction. The general picture of the mechanism of evolution thus arrived at will certainly be far from pleasing to those who regard nature as an embodiment of kindness. The writer must confess that this picture is not pleasing to him either. The words "good" and "bad" are not to be found, however, in the scientific lexicon. In this lie simultaneously the greatest strength and the greatest weakness of science.

HAHNEMANN AS A CHEMIST

By Dr. ISRAEL S. KLEINER

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"I do not know whether I am mistaken, but it seems that one can obtain more truths, important to Humanity, from Chemistry than from any other Science."

Thus wrote Samuel Hahnemann, destined to be a leading figure in one of these other sciences—medicine. They were the opening words in an article[1] describing his test for lead and iron in wine, and testified to his opinion of "this divine art" (diese göttliche Kunst). Although at that time (1788) Hahnemann was a practising physician, he probably was more active as a chemist. The greater part of his small income during his early manhood was derived from his chemical activities. This phase of his life is mentioned by all his biographers, but how excellent a chemist he really was has generally not been appreciated.

It has usually been assumed that Hahnemann received no schooling in chemistry, *i.e.*, that he was self-taught as regards this science. "In fact," says Hobhouse,[2] "the course of medical training prescribed at the university did not at that time include these subjects (chemistry and microscopy): even so famous a university as the one at Heidelberg did not introduce microscopy and chemistry in the syllabus of their medical students until 1845." It is difficult to see how any one with no training could master even the simple chemistry of that day so well that he could accomplish the important work which Hahnemann soon did.

However, such an assumption is no longer necessary. Tischner[3] has shown that Johann Gottfried Leonhardi lectured in chemistry at the University of Leipzig while Hahnemann was a student there and in the winter of 1776 gave an *experimental* course in chemistry. Since Hahnemann twice refers to Leonhardi as his teacher, it must be inferred that he studied chemistry under that instructor. He took medical courses at Leipzig from 1775 to 1777 and in the hospital at Leopoldstadt, near Vienna, in 1777. During this time he must have acquired his basic knowledge of chemistry. He obtained the degree of doctor of medicine at Erlangen in 1779, but his chemical activities continued, during his struggles to become established as a physician, until about 1789.

In evaluating his contributions, one must take into consideration the state of chemical knowledge and philosophy of his time. The last quarter of the eighteenth century covers the period of the Chemical Revolution, which eventually completely upset the current views of chemistry. It is doubtful whether Hahnemann realized the extent of this change in chemical thought, although he must have been familiar with the writings of Lavoisier, Priestley and others, as he was an accomplished linguist and an indefatigable reader. Very few chemists were able to understand how great a change in chemical theory was taking place, how beautifully the new hypotheses would explain known phenomena and how rapidly chemistry would develop as a result of Lavoisier's work. Even Priestley and Cavendish, who contributed so much to the new chemistry, interpreted their findings in terms of the old, refusing to abandon the phlogiston theory.

Although the phlogiston theory had its origins much earlier, it was developed and enunciated most clearly by Stahl, toward the end of the seventeenth cen-

1 Samuel Hahnemann, *Chemische Annalen* (*Crell's*), I: 291–305, 1788.

2 Rosa Waugh Hobhouse, "Life of Christian Samuel Hahnemann, Founder of Homoeopathy," London, 1933.

3 Rudolph Tischner, "History of Homeopathy," translated by Linn J. Boyd, *Jour. Am. Inst. Homeopathy*, 27: 548, 622, 672, 728, 1934. 28: 34, 225, 288, 358, 555, 602, 684, 749, 1935.

tury. According to this theory all combustible substances contain one constituent which escapes during combustion. It is easy to see how the early chemists came to have this conception. When a piece of wood burns, the flames appear to come out of it and the residue is distorted by this violent emergence. Naturally they concluded that something had left the wood. The alchemists first called this "sulfur"—Becher termed it "terra pinguis," while Stahl named it "phlogiston." Some substances burn more completely than others; this was explained by saying that they have more phlogiston in their make-up. Phosphorus burns to a white ash, which, when dissolved in water, is acidic. Therefore, they argued, phosphorus is a compound of phlogiston and phosphoric acid. If a metal is heated, an ash (which we call an oxide) is left—hence the metal consists of this ash and phlogiston. Now, when this calx (oxide) is heated with carbon, the carbon, (thought to be rich in phlogiston) transfers its phlogiston to the metallic ash and the metal (ash plus phlogiston) is reconstituted. Of course, we now see that the metallic oxide has been reduced to the metallic form by heating with carbon, the carbon being oxidized in the process.

There were several difficulties involved in accepting this hypothesis. The first was that no one had ever isolated phlogiston, even in an impure form. Another—and more serious one—was that when metals are burned, the ash weighs *more* than the original metal. If it loses phlogiston, it should weigh less. These flaws—and others—were shown very plainly by Lavoisier (1743–1794). This scientist in a series of remarkable experiments on combustion demonstrated the fallacy of the phlogiston hypothesis very brilliantly and in 1777 enunciated his own theory of combustion, which he later broadened to include combustion in the animal body. Lavoisier's views are essentially those held to-day. It took a number of years, however, before they were accepted even by his contemporaries in France. Since Hahnemann was a master of French it is probable that he was among the first in Germany to study Lavoisier's work. Haehl[4] says, "Hahnemann became acquainted, in Dresden, with the famous French chemist, Lavoisier, who was at the time passing through Dresden." If this occurred—and Haehl gives no authority for his statement—it must have been between 1785 and 1789, and in 1788 he used the expressions "phlogistierter" and "dephlogistierter."[5]

It is probable that Hahnemann's early chemical studies were entirely from books —although he possibly saw laboratory demonstrations by Leonhardi. His first real contact with a laboratory was made in 1781 when he moved to Dessau. This was not far from a mining district in the Harz Mountains and when he began to study metallurgy he naturally required some laboratory facilities for this work. These were found in the local pharmacy of Herr Haseler, whose step-daughter proved an added inducement to visit the shop. He fell in love with her and later married her. It must have been this intimate relationship with the pharmacist and the use of his equipment which enabled Hahnemann to get a first-hand knowledge of drugs, their manufacture, adulteration and the various problems of the pharmacist. The pharmacists in those days were almost the only chemists. Of course, there were a few teachers of chemistry in the universities and a few independent savants, and, perhaps, still some alchemists. There was also some

[4] Richard Haehl, "Samuel Hahnemann, His Life and Work," translated by M. L. Wheeler and W. H. R. Grundy, London, 1922; Hobhouse (footnote 2) makes a similar statement and cites Ernst von Brunnow ("A Glance at Hahnemann and Homoeopathy," Leipzig, 1844, translated by J. Norton, 1845) as authority for the assertion that Hahnemann corresponded with Lavoisier.

[5] Samuel Hahnemann, *Chemische Annalen* (*Crell's*), I: 141–2, 1788.

chemical manufacturing. But the names pharmacist and chemist were almost synonymous and even to-day this is the case in many parts of Europe. Hahnemann remained at Dessau only a short time and then moved to Gommern. This town was not very far away, so that he still could use Haseler's facilities, as well as those of the pharmacist in his new location. The new situation, although yielding a better salary than the former, gave him little clinical work, and consequently he had more time for chemical study and investigation.

These studies directed his attention to a book by Demachy on the wholesale manufacture of chemicals. This was a work of great importance because it described methods which had been kept secret by manufacturers, particularly the Dutch. Hence Demachy's book had been welcomed by the French and by those of other countries who read that language. Hahnemann now translated it into German, and, because of his familiarity with pharmaceutical chemistry and his indefatigable reading of the literature, he was enabled to enlarge and improve it. After he had finished translating this work, but before publication, another translation, by Struve of Berne, appeared. This also had some new material. Consequently, Hahnemann included Struve's comments and published the enlarged work. He supplied missing references to the literature—in fact, he frequently cited a number of additional authorities whom Demachy and Struve had overlooked—and amplified with details, as, for example, the history of a discovery, the chemical reactions involved and various manufacturing details which had escaped Demachy.

It is not surprising that many erroneous ideas were presented. For example, the purity of nitric acid was estimated by the amount of white precipitate produced when a silver solution was added to it. This, of course, was caused by hydrochloric acid present. "Such impure nitric acid must indeed have acted as aqua regia, and it is therefore not astonishing that that excellent chemist, Struve, observed a deposit of gold from a 'solution of silver.' (Hahnemann calls this idea 'an alchemistic fancy.')"[6] This parenthesized remark is interesting as intimating where Hahnemann stood on the subject of alchemy, in a day when alchemy was not completely discredited. Other interesting misconceptions were that the older potash becomes the more potassium sulfate it contains, that milk sugar consists of one part chalk and three of saccharic acid, and that cinnabar (mercuric sulfide) owes its red color to the fatty acid which it has derived from fire. Since this was published in 1784, it is not strange that his discussions should include references to phlogiston. It was not until several years later that Lavoisier's conclusions were generally accepted.

In spite of these errors, the work was extremely valuable, and many of the errors of the original were corrected by the translator. Several new tests were added by Hahnemann. The test for hydrochloric acid at that time was "lunar caustic" (silver nitrate) alone. This might precipitate sulfuric as well as hydrochloric acid unless a considerable degree of dilution was used. Hahnemann used a solution of silver sulfate, which of course would not precipitate sulfuric acid. He also proposed a new test for sulfuric acid (lead chloride) and described Scheele's new baryta reaction for the same acid. This book was very well received and, indeed, was standard for several years. A new edition was issued in 1801.

A number of papers by Hahnemann appeared from time to time in the journal, *Chemische Annalen für die Freunde der Naturlehre, Arzneygelahrkeit, Haus-*

[6] Wilhelm Ameke, "History of Homeopathy," translated by A. E. Drysdale, London, 1885.

haltungskunst und Manufacturen, which was edited by Lorenz Crell. Some of these were "preliminaries" to parts of his books or omissions from them or amplifications of procedures previously described. They abound in detailed descriptions of technique, resembling very closely the directions for preparing homeopathic medicines which he later published. For example, in his work, "On the influence of different gases on fermentation of wines,"[5] he explained how he introduced the wine (eight-year old Meissner) and the gases into flasks, the amounts of each used, the method of hermetically sealing them, and the temperatures at which they were kept for two months. They were shaken "thrice daily with thirty strokes up and down," and he assures us that all were agitated to about the same degree. His experiments always were carefully performed and meticulously described.

A monograph on arsenical poisoning was published by Hahnemann in 1786. In it he gave the determination of the lethal dose, pathological effects as well as the best methods of analyzing for arsenic. He suggested several tests for arsenic, some of which are still recognized, *e.g.,* the use of an ammonium cupric salt (Hahnemann used the chloride) to precipitate the bright green cupric arsenite (a reaction which he found to be positive at a dilution of 1 in 5,000.) He also recognized the necessity of an acidic reaction in the precipitation of arsenical compounds by means of hydrogen sulfide and thus demonstrated the reason why others had found this reaction indefinite. This apparently minor point of acidification in certain qualitative tests is exceedingly important.

A little later he translated, and, as was his habit, improved and enlarged J. B. Van den Sande's "La falsification des medicaments devoilee." This handbook on the adulteration of drugs contained much useful information, including methods of testing for adulterants, solubilities of various metallic salts and the relations of the specific gravities of acids to their concentrations. It was in this volume that his celebrated "wine test" was described. This was really a test for lead as distinguished from other heavy metals. It is stated that simultaneously and independently Fourcroy made and published the same test in France. Lead was often added to wine in those days, probably for the preservative effect, and lead poisoning resulted frequently from its use. It was necessary, therefore, to test wine for lead in court cases resulting from poisoning and in suspected wines. The current test was to add "arsenical hepar sulphuris" to the wine. This reagent was prepared by boiling two parts of arsenious sulfide with four parts of unslaked lime in twelve parts of water. This reagent when added to wine containing lead salts would produce a dark precipitate of *lead sulfide.* However, other metals would yield a similar result. For example, any iron present—as might result from the presence of pieces of iron chain or iron screw heads in the cask—would give a positive reaction. It sometimes happened that innocent dealers were convicted on the strength of this test. Hahnemann, realizing the inadequacy of the test, determined to attempt to evolve a better one. After careful study, he came to the conclusion that a satisfactory method was to add hydrogen sulfide water ("Leberluftwasser") and then acidify.

Lead sulfide, a black precipitate, forms under these conditions, but iron sulfide is soluble in the acid. Again the importance of optimum hydrogen ion concentration! It is not a specific test for lead, but the metals which give positive reactions either would not or should not be in wine, *e.g.,* silver, copper, mercury, arsenic, etc.

Hahnemann's directions for preparing the reagent were as follows. First

"hepar sulphuris calcareum" is prepared by heating at white heat for twelve minutes equal parts of oyster shells and sulfur. The whitish gray powder, the essential ingredient of which is calcium sulfide, may be kept unaltered for years. Two drachms of this are placed in a bottle, a pound of water added and ten drops of muriatic acid for every ounce. The strength of acid is not stated, but presumably the strongest then available was used. If this reagent is added to wine, a black precipitate indicates a considerable amount of lead, a brown to brownish-yellow discoloration points to small quantities. In the presence of acid iron does not react. Although the first description called for muriatic acid, later cream of tartar was used and still later Hahnemann called attention to the fact that his technique must be followed exactly or else failure might result. In order to be sure of the acid reaction he then described his new "Liquor probatorius fortior,"[7] which consisted of tartaric acid and calcium sulfide ("Kalkschwefelleber"). To-day the acid is added directly to the suspected fluid and hydrogen sulfide gas is bubbled in—but the same principle is involved. In Hahnemann's hands, the test was positive up to a dilution of 1:30,000.

A *quantitative* method for lead was soon worked out in which the metal was precipitated as the sulfate. After filtering and drying, this was weighed and due allowance was made for the solubility of this salt.

It is thus seen that Hahnemann was an excellent chemical investigator, not a mere analyst following slavishly the methods he found in vogue. He was ingenious in improving apparatus and devising new appliances. He was careful and exact in his quantitative measurements. He had an almost uncanny power of sensing how a reaction would proceed. When one realizes the flimsy foundation upon which chemistry rested in those days, Hahnemann's accomplishments—of which but a part have been mentioned—must be termed remarkable. It has been asserted that Hahnemann was really the founder of colloid chemistry. This is based on the pronouncement that "all medicinal substances brought into potency 1 (one-millionth) by trituration in powder are soluble in water and alcohol."[8] The procedure, he asserted, was unknown to chemistry and was "a discovery which I announce to the world for the first time." It is evident that he was probably the first to produce suspensoids by his process of repeated trituration and dilution, but since he did not study their nature and properties physico-chemically, we can hardly dislodge Graham in favor of Hahnemann.[9] In fact we must remember that these preparations were made for medicinal purposes, long after Hahnemann's chemical career had ended.

It is idle to speculate upon his probable place in chemistry if he had continued in this science. With such contemporaries as Lavoisier, Priestley and Cavendish he would have had competition which might have stimulated him to extraordinary activity or might have overshadowed him completely. In medicine his place is unique and his importance is being recognized more and more. That he was not only a medical pathfinder but a good chemist—perhaps a potentially great one—adds another name to the list of versatile scientists, such as Abbé Spallanzani, Lavoisier, Benjamin Franklin and Pasteur.

[7] Samuel Hahnemann, *Chemische Annalen* (*Crell's*), I: 104–111, 1794.

[8] Samuel Hahnemann, "Chronischen Krankheiten," 1828, Vol. II, p. 5; quoted by Tischner (footnote 3), p. 674.

[9] Linn J. Boyd, "A Study of the Simile in Medicine," Philadelphia, 1936. See p. 38.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

THE FINANCIAL SUPPORT OF RESEARCH

Research is the lubricant that makes the wheels of civilization turn faster. Without it, industry and agriculture would not accelerate but would slow down and perhaps even stop all together. The financial support of research is therefore important. It is a matter of more than idle curiosity as to how many dollars are being spent for research, dollars plowed back into our workaday world to produce more scientific dividends in dollars and better living.

In good round figures, somewhat over a cent is spent for research out of each dollar grossed by U. S. manufacturing and agriculture, according to figures collected from a score of sources. Industry spends more than agriculture, 1.7 per cent. (some $250,000,000) out of the $14,690,000,000 gross manufacturing income of 1936. Agricultural research, almost wholly by state and federal institutions, used 0.37 per cent. or some $35,600,000 of the estimated $9,530,000,000 cash farm income and value of home consumed farm products combined.

In terms of population, the total for research expenditures in these two great fields is only a couple of dollars per person in the U. S.

When such compilations are made, the question arises as to what to include in the figures for research. The historian who is looking into some problem can rightly say he is engaged in research. But the figures quoted are largely for inquiries and developments in the physical and natural sciences, the fields in which chemists, physicists, engineers, biologists, etc., work.

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

Chemical concerns practice research to a larger extent than the average. Here are some reports: 2.3 per cent. of net sales; 2.4 per cent. of gross sales; 5 per cent. of net sales; 7 per cent. of net sales, etc.

Medicine and health fields see considerable expenditures for research, the results of which are mostly measured in better health and less human suffering.

Research pays magnificently, often thousands of per cent. in dollars and more in gains to civilization.

THE STROBOSCOPIC CAMERA

Ranking with the microscope and the telescope as a scientific aid to human eyes is the high speed stroboscopic camera that has reached a peak of development at the Massachusetts Institute of Technology.

Our eyes can not see things that are moving with great rapidity. If we "freeze" a hundred thousandth of a second of some speedy motion by illuminating it with a spark of such extremely short duration, the scene will appear motionless. It can be recorded upon a photograph so that we can look at it for a longer time than that very short interval.

That is what is done by Professor Harold E. Edgerton and his associates, K. J. Germeshausen and H. E. Grier in laboratories on the Cambridge, Mass., campus. They can catch a bullet coming out of a rifle's muzzle, the dangerous shiver of high speed machines, and other happenings that better the proverbial wink of an eye.

Far from being just a stunt, such

speedy stroboscopic photography promises to be extremely useful practically. Professor Edgerton has a unique ultra motion picture camera that can speed up to 6,000 exposures per second. Linked to the brilliant spark-flashing stroboscope, this camera runs at such closely controlled speeds that precise measurements of accelerations, velocity and other factors can be made on the film.

The "studio" for photographically "seeing the unseen," contains a whole roomful of electrical apparatus, mostly concerned with producing suddenly released high voltages that produce the photographic sparks.

The stroboscopic camera is eminently suitable for clocking projectiles, whirling engines and propellors and other mechanical devices, but even medicine is using it to study the action of high speed microorganisms.

WARM WALLS AS A METHOD OF HOUSE HEATING

It was Mark Twain who said that every one talks about the weather but no one does anything about it. Each year, however, science and engineering make the famous humorist's quip slightly less applicable.

Weather, of course, is only another name for man's atmospheric environment. At least that aspect of weather is one of the most important to human welfare.

As Professor Earle B. Phelps, of the College of Physicians and Surgeons, Columbia University, recently said, "By means of clothing, umbrellas, shut-in cars and other sheltering devices we do maintain, even in our travels, a sort of personal weather environment and, when we confine the weather within walls, we do with it as we will."

Health and comfort, Professor Phelps goes on to add, demands a balance among the various manners of heat loss of the body in addition to an over-all balance between production and total loss. "An arctic explorer, in his furs, and a swimmer in the surf of Atlantic City may both be disposing of the same number of calories per hour, but one would hardly class the two environments as equivalent," he declared. Yet each man might, at the moment, be equally comfortable.

Indoors it has long been recognized that air temperature, humidity and movement are all factors in determining comfort. But also it is now recognized that there is a fourth factor, the temperature of the walls of the room. It has been shown that radiation from the body to the walls may account for nearly half the body's total loss of heat. It has been on these findings that home heating of the future has often been predicted as consisting of heated walls.

STATIC ELECTRICITY IN THE SEPARATION OF ORES

Every small boy who has ever rubbed a piece of sealing wax with cat's fur and attracted to it bits of paper knows that in the forces of static electricity lies one means of separating materials. Mining engineers long ago realized that somehow static electricity might be used commercially to separate valuable from worthless ores.

The idea is old, of course, but it never has been applied widely and successfully to large-scale separation of ores as have the magnetic separation and various flotation methods. The trouble was that the sources of static electricity—the old-fashioned Wimshurst machines and so on—were ineffective. Later the use of transformers and mechanical rectifiers of current arrived and some improvement came also. But, as H. B. Johnson reports to the American Institute of Mining and Metallurgical Engineers, there has been little development in the last ten years despite great advances in the radio and vacuum tube art in that decade.

Mr. Johnson has studied the electrostatic separation of over 90 different elements with a simple and ingenious apparatus. The mineral mixture to be separated feeds down a hopper on to the surface of a rotating cylinder charged electrically positive. Nearby this cylinder is another one charged with electricity of the opposite sign by using a full-wave high-voltage rectifying tube. The voltage created sets up a strong electric field that pulls the falling particles out of line in their vertical fall and makes them drop on the other side of a suitable vertical dividing sheet of material. Thus one component of the mixture falls on the one side and the unattracted particles on the other.

Mineral granules the size obtained in commercial grinding machines were used in the tests. One difficult separation achieved was the removal of bituminous coal dust from anthracite dust. Among the difficult separations made possible were those of separating (1) galena from pyrite, (2) muscovite from lepidolite (both micas) and (3) calcite from dolomite.

A TUNG OIL SUBSTITUTE

Japan is conquering China foot by foot. Already the economic consequences of their control are felt in the world markets, mainly as a stopping of Chinese exports like tung oil. Realistic business sees conditions becoming worse before they become better and hence is enlisting the aid of scientific research to find some substitute for the fast-drying vegetable oil which finds such wide use in paints and lacquers.

Which brings us to oiticica oil. This oil comes from pecan-like nuts from Brazil's oiticica tree. Oiticica oil (pronounced oy-tee-see-kar) is the only vegetable oil, available in commercial quantities, which rivals tung oil in its properties.

While you can follow the Japan-China troubles in the newspaper headlines you can also read them, by inference, from the tables showing Brazil's exports of oiticica oil. Prior to 1934 these exports were negligible. In 1935 exports of oiticica oil totaled 4,000,000 pounds and in 1936 they jumped to between 8,000,000 and 10,000,000 pounds. In 1936 the United States took 3,000,000 pounds of the total and in 1937 the amount increased to 4,000,000 pounds. World export figures for 1937 are not yet available.

Research is showing how the oil can give both smooth and crinkly surfaces to paints and lacquers. Early work, in which the oil was processed like tung oil, gave discouraging results that are now being overcome.

Oiticica oil seems especially adapted for use with phenolic resin lacquers of which bakelite is typical. The crushing of the nuts in northern Brazil is now done in modern factories which bid fair to set up a new oil source despite any events which may occur in the Far East. Chemists in Germany, England and France, as well as the United States are studying the oiticica oil.

FLYWAYS OF BIRDS

Birds flying northward, as heralds before the face of the returning springtime sun, follow paths as definite as those laid out for pilots of transcontinental planes. These can be traced by noting numbers on leg-bands of captured birds and then releasing them again, and also in a more general way by observers stationed at strategic points along the "flyways."

North America has four major flyways, with of course a number of feeders and branches. The four great paths follow Atlantic and Pacific coastlines, and in the interior, one along the east flank of the Rockies, over the Plains, and one down the great central valley with the Mississippi as a broad silver guideline.

Europe likewise has well-established

flyways. Two of them cross Switzerland. One, originating in Russia, skirts the Baltic countries, Poland and Germany, and thence into northwestern Switzerland. The second comes from Finland and northern Scandinavia. At the Rhine delta it divides. One branch toward the south goes *via* the coast of France and the Iberian peninsula. The other swings inland along the Rhine and eventually reaches northwestern Switzerland.

Unlike our North American birds, the birds of Europe that follow these inland routes have mountain barriers to climb. Passes become as important to them as to land animals—or even to airplanes. Thus is has come to pass that Switzerland is a strategic center for the study of migrating birds, and also that Swiss refuges possess high importance for the conservation of European bird life. In view of the ominous clouds now hanging over all Europe it is perhaps well for the birds that this is so.

WILD PIGS AND GOATS

Hawaii seems to have been a paradise that escaped the trampling hoofs and devouring mouths of the Age of Mammals, almost entirely until the coming of that most troublesome of all mammals—Man. To introductions and changes wrought by human agency are traceable most of the damage and destruction to the unique vegetation of the islands.

Some of these disturbances were described before the North American Wildlife Conference at its Baltimore meeting by Samuel H. Lamb, assistant park naturalist of Hawaii National Park. Although Mr. Lamb confined his discussion to problems within the national park boundaries, he stated that in many ways these are typical of conditions for the countryside at large.

The only mammal that seems to have found its own way to Hawaii unaided by man is the bat. The original brown-skinned immigrants brought dogs and perhaps pigs, and they may have carried rats and mice as stowaways. Other students of the problem believe that the pigs, rats and mice date from a supposed visit by the Spaniards in the sixteenth century. Goats were brought by Vancouver in 1794, and other live stock came later.

Of them all, most destructive to Hawaiian native vegetation are goats and pigs, escaped from domestication and now living as wild animals in the rough, wild interior, in part thickly forested, in part grassland and semi-desert lava fields. Goats are notorious everywhere as destructive feeders. Pigs are even worse, for they root underground, devouring bulbs and rootstocks, and breaking the ground cover to give alien grasses and weeds a chance to gain roothold.

Efforts to save at least part of the native vegetation include goat-tight fences around selected areas, followed by concerted drives to eliminate the feral animals within them. In broken lands where fencing can not be carried out, the only thing that appears practicable is to permit and even encourage wholesale shooting of the goats and pigs.

A CANADIAN BONE

Canada can prepare for scientific war. Discoveries of "oldest inhabitants" have begun to be reported. If experience of the United States means anything, from now on Canadians will be arguing endlessly over whether fragments of human bone and odd-shaped stone blades are evidence of Ice Age man in Canada, or just relics of later and less exciting Indian tribes.

The incident creating an early-man-in-Canada situation occurred when workmen digging gravel for a road near Bradwell, Saskatchewan, turned up something unexpected—a skeleton.

They called in Canadian mounted police; but the detective sergeant realized this was no murder mystery, at any rate, none of recent date. So, he called these

antique-looking bones to the attention of a scientist, who happened to be a chemistry professor at the University of Saskatchewan. The professor rounded up three more professors—a chemist, anatomist and geologist—and proceeded to the scene.

Meanwhile, the road builders hauled off more gravel. The scientists, thus confronted with a mystery scene much disturbed, have concluded tentatively that this unknown was a primitive man of considerable antiquity. In short, "an interesting example of early man in America."

As clues to antiquity, they mention the heavy, mineralized bones; also that the skeleton lay in gravel deposited when the Keewatin ice sheet was retreating, some 15,000 or 20,000 years ago. The bones are compared to those of Neolithic men of Europe. A nondescript stone tool was nearby.

And now, what next? Undoubtedly, some cautious scientist will rise to point out that this man could have lived after the Ice Age and be buried intrusively in glacial ground. Whether the skeleton is an ancient type, or just recent Indian, will be good for many an argument. Canada may yet find conclusive evidence of early inhabitants.

DIGGING SHOWS WHY ROME FAILED IN ANCIENT BRITAIN

Once again the past teaches a lesson in conquest and its results.

Archaeological investigation in England is revealing what written history has never explained: How and why Rome failed to Romanize barbarian Britain, 2,000 years ago.

Rome failed, says Dr. R. E. M. Wheeler, London University archaeologist, because Rome tried in Britain to introduce too revolutionary an upheaval in a social order.

Rome brought a pattern of city life which was new to the Britons because it centered around commerce. Excavations show that the Britons had their own cities. But the citified Briton was bucolic. He drew on the nearby countryside for food and for the stone, iron, clay, bone, and horn that made weapons and household gear. Rarely did these prehistoric Britons import foreign luxuries. Their trade was petty.

Came the Romans, and they set about improving these people. Native towns that resisted were stormed and dismantled, as has been recently shown by digging at Maiden Castle. Disarmed townsfolk remained to rebuild their houses and become Roman subjects.

The Romans introduced foreign craftsmen to teach the natives to build in the Roman way, and foreign capital to develop resources of the country.

By the middle of the second century, says Dr. Wheeler, London and Verulamium "shone brightly on the provincial landscape." Britain had acquired central heating, dust-proof floors, bath suites.

But, "little more than a century later the bubble had burst." Another century, and Romano-British cities degenerated into concentrated slums. No prosperous middle class had developed, and without this type the Roman city plan was bound to fail.

Dr. Wheeler sums it up: Rome effected a political and social revolution in Britain, but not the economic revolution to fit it. Romano-British country life succeeded. The cities awaited the middle ages for a come-back.

THE PROBLEM CHILD

Defiant, restless, truant and subject to temper outbursts. This is a picture of what school officials know as a "problem child."

It is also a typical picture of a child who has failed in learning to read, write and cipher—particularly to read, Dr. Charles L. Vaughn, of Detroit's Psychopathic Clinic, has learned from a study

of boys at the Wayne County Training School.

These boys were from 12 to 15 years old and yet tests showed them to be below grade three in reading. In other words they had spent about nine years in school trying to learn to read without success.

It is hard to realize the insult that such a prolonged failure is to a child. If he can not learn to add, that is to some extent at least a private matter between his teacher, his parents and himself. He can hide those arithmetic papers with the damning zeros.

But when it comes to reading, he is asked to stand up before the whole class and demonstrate almost daily his weakness.

If you have struggled with an income-tax blank, a difficult cross-word puzzle or one of those baffling Oriental cut-up puzzles, you know the exasperation that can result from failure even when no audience jeers at your mistakes.

A child should not be forced to learn to read and to try to master other school subjects until his mind has matured sufficiently to make it possible, is Dr. Vaughn's conclusion.

Teachers should try new methods of instruction with the child who is not learning, or else the child should be given another type of program, such as handwork, that he can master.

No child should be forced to submit to ignominious failure until his whole personality is disorganized, and catastrophe brings him to the psychopathic clinic.

WASHING REMOVES VITAMIN D RAW MATERIAL FROM SKIN

You play a few sets of tennis or toss a medicine ball or take some other kind of vigorous exercise in the sunshine. You come in to the shower feeling full of pep and vitamins. You rub yourself down briskly with a rough towel, and feel even better. But you've lost a good part of the vitamin you have just been acquiring!

For now it appears that the shower and rubdown that are orthodox parts of the American exercise and health ritual actually remove from the skin some of the stuff that vitamin D is made of. This is the conclusion of experiments at the Institutum Divi Thomae in Cincinnati, performed by Agnes C. Helmer and the Reverend Cornelius H. Jansen.

In the experiments, groups of students, after exercising, had their bodies above the waist washed with clear water, which was all carefully saved and evaporated down. The terry cloths with which the students dried themselves were also saved. The residue from the washing and the terry cloths was extracted with ether, and the material thus obtained subjected to ultra-violet irradiation and fed to rats afflicted with rickets.

The defective bones of the rats healed up, showing that the athletes' "washings" had contained the precursor or raw material for vitamin D, which was then converted into the vitamin by the ultra-violet treatment.

In a second experiment the students were first irradiated with ultra-violet and the extracts then made in a similar manner. The results with rats proved that the washing had removed vitamin D itself from the boys' skins.

In their conclusions the experimenters state: "There is definite evidence that the secretions from the skin contain precursors of vitamin D, which after irradiation are due to be reabsorbed by the body, and the removal of which tends to produce a dearth of the vitamin unless it be supplied in some other form."

THE USE OF MAPS IN FIGHTING DISEASE

Most newspaper readers are familiar with the pin- or flag-marked war maps that show the advancing or retreating lines of conflict and other important information on which battle plans are laid. Some of you have doubtless kept such

maps of your own for handy reference when following war news.

Did you know that the great army of health experts which fights to protect us from disease has similar war maps? They hang on the walls of every health department (or should) to give information as to the whereabouts of the enemy and his strength. They are charts showing daily, weekly, monthly and yearly reports of cases of communicable diseases.

The battle lines, marked usually by colored pins, show the advance or retreat of various disease enemies. These lines are called curves. Sometimes, as during epidemics, they are sharply pointed, advancing rapidly to a high peak and usually falling down more slowly to the normal or expected level of cases for that particular disease. The continuous downward sweep of other curves shows the triumph of medical and health science over a particular disease.

Looking over the curve of monthly mortality rate from all causes of death combined, for all ages, Metropolitan Life Insurance Company statisticians find that the enemy has been driven back on one important sector. This consists of the summer months when the death rate formerly ran high chiefly because of "the slaughter of young children by intestinal diseases." Improved sanitary conditions and purer milk and water supplies are the big guns that have broken down the enemy lines on this sector.

The health armies are concentrating now on driving back the enemy lines in the cold season of the year. This means hard fighting against pneumonia, colds, influenza and also on the chronic diseases of heart and kidneys of old people.

STRESS IMPORTANCE OF EARLY DIAGNOSIS IN TUBERCULOSIS

Early diagnosis is half the battle in fighting tuberculosis. When the disease is discovered in its early stages, authorities state, the patient has a good chance for early recovery. The later it is discovered, and the longer the patient puts off starting treatment after diagnosis, the worse his chances get for recovering.

Early diagnosis is important not only for the patient's sake. It is important for protecting his friends and family and the people he works with. Every case of tuberculosis in the infectious stage is a possible source of many more cases. Children are particularly likely to get tuberculosis when some member of the family or household—a servant or boarder or roomer—has the ailment. Once the disease is recognized, however, precaution may be taken to protect children and others in daily contact with the patient.

Recognizing the importance of early diagnosis, the National Tuberculosis Association and local branches throughout the country sponsored an intensive early diagnosis campaign in April. They have urged every one who has any suspicious symptoms which might mean tuberculosis to see a competent physician at once. With a skin test, called the tuberculin test, and with x-ray pictures of the chest, the physician can determine whether or not the patient has tuberculosis. The patient himself, however, must be on guard for the early signs of tuberculosis and take himself promptly to a doctor if he develops any.

The National Tuberculosis Association lists 6 early danger signs of tuberculosis. One is feeling tired all the time when you have nothing to feel tired about. Another is constant loss of weight and strength. If you don't care for food, that's a danger sign. So is a cough that hangs on and on. A pain in the chest that gets worse when you take a long breath is the fifth danger sign. Finally, spitting up blood is a danger sign.

THE SEARCH FOR LONGEVITY[1]

By Professor RAYMOND PEARL
THE JOHNS HOPKINS UNIVERSITY

I

THE available evidence indicates that during the last twenty-four hours something upwards of a sixth of a million fresh new human beings have appeared for the first time upon this earth as a whole. In other words, there has been delivered on our planet to-day well over 600 tons of that strange mixture of water, mineral salts and colloids called human living substance. For delivery this material was neatly wrapped up in a lot of little packets that we call babies. These packets have been turned out to-day at a rate not much below two a second over the whole world. I speak of to-day's activities in the production department of human biology, merely because people like their statistics up to date. But the same sort of thing, in round figures, went on yesterday, and will occur again tomorrow, so we may as well focus attention on to-day's crop as any other.

Each one of these squalling blobs of protoplasm that starts to-day on the journey through time called the life span will endeavor, with all its might and main, to make that journey last just as long as possible. For the will to live, the quest for longevity, is the most deeply rooted and persistent of the biological characteristics of protoplasm organized into individuals. At the beginning of each person's life this urge to survival is wholly unconscious, just a part of living, like digestion or respiration; later on, this underlying protoplasmic will to live, the vital momentum, will be supplemented in the individual by a conscious search for longevity. The great part of to-day's babies who manage to survive until they are somewhere in the twenties will then begin to think a little about what they should do to preserve their health so that they may keep on living longer. Virtually all of them who live until they are seventy years of age or upwards will think about little else from that time on. For it is an odd but profoundly true generalization of human biology that the longer a human being has lived, the more anxious and personally concerned he is, by and large, to keep on living still longer. The octogenarian or nonagenarian may be in wretched health and altogether having a bad time of it, but even so his normal and sound instincts are for keeping on.

Incidentally, it is the almost universal lack of appetite for dying that makes the medical profession a possible one. At the moment, as every one knows, the profession is being wracked with discussions and torn with dissensions over its economics. But if mankind had not, from its remotest antiquity, been profoundly of the opinion that the physician could be of significant help in the struggle to keep on living there would be to-day no question of medical economics to discuss. Physicians are employed, and sometimes are paid, because people fear death and hope to keep on living. And doctors are not the only ones employed and paid for the same reasons. In spite of everything the honest, wise and sincere members of the profession have been able to do, from the time when that arch quack Alexander of Abonutichus and his partner Cocconas practised their deplorable knavery down to the present, a horde of dubious charlatans of all complexions and degrees have fattened off humanity's dis-

[1] Presented as one of the Third Series of "Lectures to the Laity" of the New York Academy of Medicine on February 24, 1938. Published here with the consent of the academy.

taste for dying. It has been revealed to many others besides the unworthy Alexander that, as Lucian said, "human life is under the absolute dominion of two mighty principles, fear and hope." Neither the art nor the science of medicine have as yet, alas, achieved an altogether complete understanding of life or or what to do to prolong it in the individual. The patient sometimes becomes impatient because this is so. Then, so compelling is his survival urge, he turns more often than would happen in a truly rational world to the ministrations of the quacks. Man's reason is evolutionally his most recent acquisition, so perhaps it is not altogether strange that it should be so easily overset by his baser biological instincts.

II

The duration of the journey through life that so many young hopefuls have started upon to-day will vary greatly amongst them. Some of the lot will end it to-morrow, so incomplete is their vital resource and so fragile their design for living. Others, a very few others, of the lot will be living a hundred years from now. The tired eyes of these will have seen many strange happenings in a dizzy world before their journey is done.

The pattern of these varying life journeys and the changes in that pattern in quite recent years are matters of considerable interest and worth looking into on their own account as well as to give us a more solid ground for the further discussion of human longevity. The "order of dying" of a cohort of individuals all born at the same time is given with great accuracy by a device known as the life table, that combines mathematics and biology in a happy and useful mating. For purposes of the present discussion a certain function called the "survivorship" for two life tables has been put in a graphic form, on the supposition that the life journey of which we have been speaking consists in climbing a long and huge ladder. The first of the two life tables chosen for this treatment is one of the latest comprehensive American life tables. It combines into one single well-digested whole the mortality experience of the United States (exclusive of Texas and South Dakota) for the years 1929 to 1931, inclusive. This table was computed and published by Louis I. Dublin and Alfred J. Lotka.[2] The second table to be depicted is that of James W. Glover.[3] based upon the mortality experience of the State of Massachusetts in the year 1890. In both cases we shall deal with the order of dying of white males only. What will be shown is the shape and dimensions of the ladders of life which the respective cohorts of white boy babies —that of 1930 and that of 1890—may be imagined as climbing.

The construction of the ladders is as follows: the total length (or height) of each ladder is the total *span* of life, which is about the same in each case—a little over 100 years. The rungs of the ladder are in each case set ten years of age apart, so that the bottom rung of each is at 10 years of age, the second rung at 20 years, and so on. The length of the rungs—or width or spread of the ladder —is, at each rung, proportional to the numbers of persons in the cohort who live long enough to get a foothold on that rung. Naturally, both ladders are drawn to the same scale in the picture. In both cases 100,000 just-born white male babies

[2] Dublin and Lotka, "Length of Life. A Study of the Life Table." New York: Ronald Press, 1926. Pp. xxii + 400. The life table is on pp. 14–17. The preliminary report of other official United States life tables for 1930, prepared in the Division of Statistical Research of the Bureau of the Census, was published in July, 1936, by Joseph A. Hill (*Vital Statistics—Special Reports.* Vol. I, pp. 389–399). For whites these tables are essentially similar to those given by Dublin and Lotka.

[3] J. W. Glover, United States Life Tables 1890, 1901, 1910 and 1901–1910. Washington (Govt. Printing Office), 1921. The table discussed here is on pp. 132–133.

are supposed to start together climbing the ladder. In the case of the 1929–31 ladder there has been placed opposite each rung a calendar year date. This is meant to suggest that it will be a ladder of life much like the one here depicted that the white American boy babies born to-day will climb. This is not an entirely wild bit of prophecy, because past experience indicates that the ladder they will ascend will almost certainly actually be as good as or better than this one, because it is not likely that medical and public health progress will abruptly stop to-night. It is progress in these two fields in the recent past—within the lives of most of us here to-night—that in large part has wrought the 1929–31 ladder of life into the shape seen in Fig. 1. To be sure other things have been concerned in the matter too—such as improvements in the general conditions of living and of getting a living and in general education—but the forward strides of medical and public health knowledge and practice have surely been the most conspicuous causal elements involved.

It is at once evident that the two ladders, less than half a century apart in time, are quite different in shape. The one for 1930 has an air of broad substantiality—a solid structure that holds a lot of people. The 1890 one stands on the same base, but after the lowest rung is passed becomes a rather narrow, gangling thing, with much less of an air of solid stability; resembling strikingly the sort of ladder built for fruit picking,

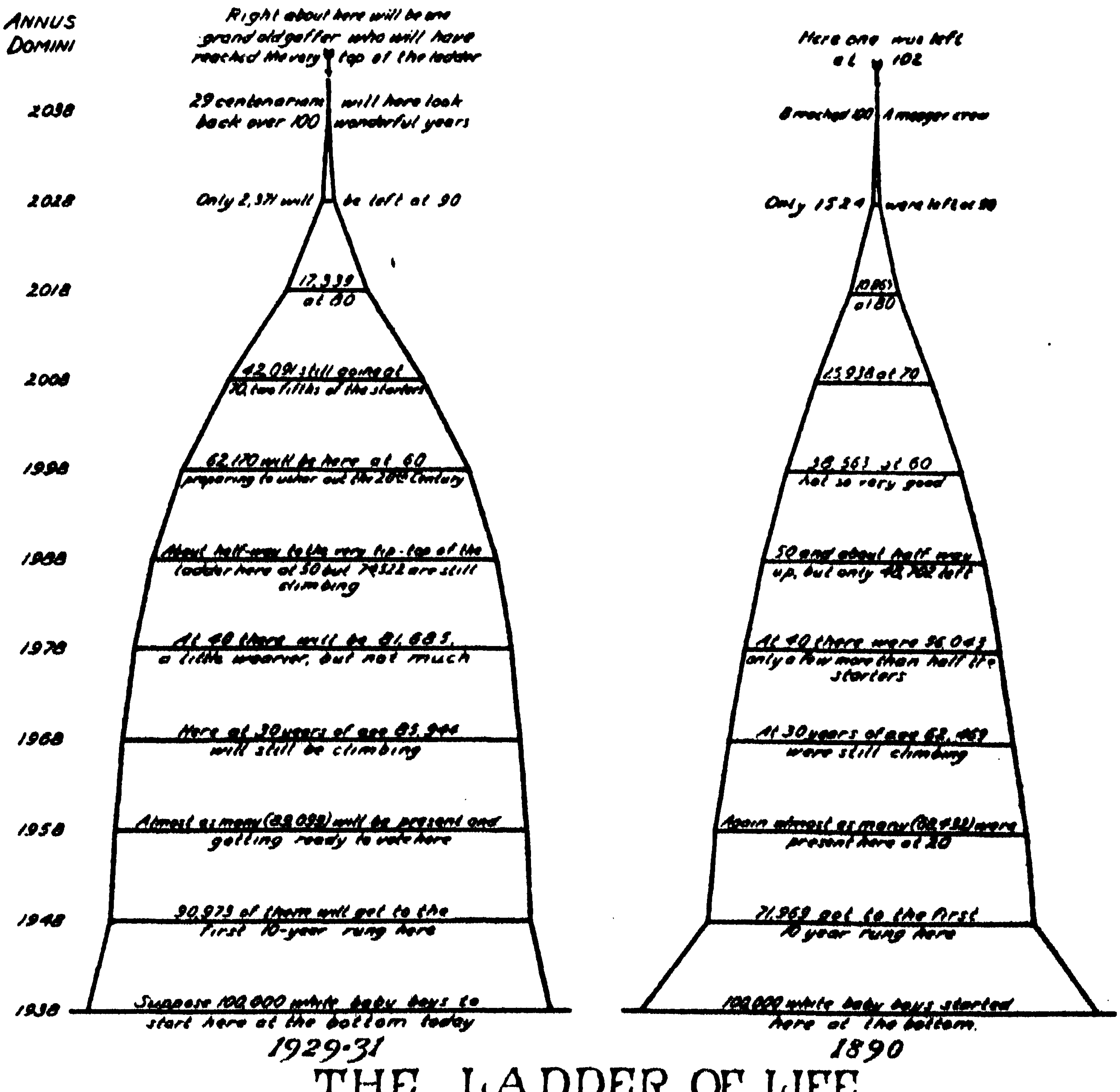


FIG. 1. THE LADDER OF LIFE, AS IT IS SHAPED NOW (ON THE EVIDENCE OF 1929–31), AND AS IT WAS IN 1890, FORTY-EIGHT YEARS AGO. FOR FURTHER EXPLANATION SEE TEXT.

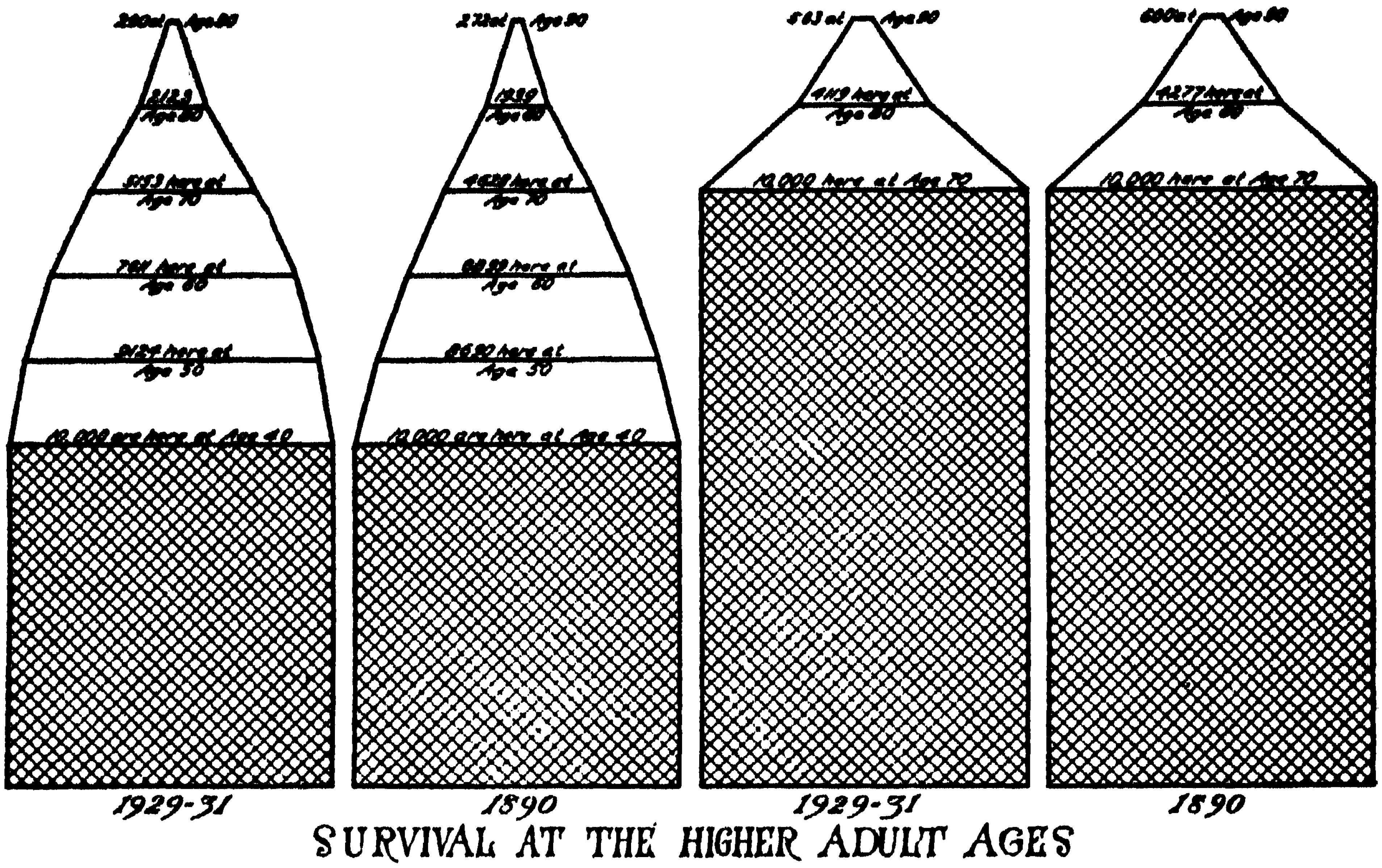


FIG. 2. THE NUMBER OF SURVIVORS AT THE LATER AGES FROM AN EQUAL NUMBER STARTING AT AGE 40 AND AT AGE 70, AS SHOWN BY THE U. S. LIFE TABLE (EXCLUSIVE OF TEXAS AND SOUTH DAKOTA) OF 1929–31, AND THE MASSACHUSETTS LIFE TABLE OF 1890. WHITE MALES.

rather than the broad and heavy firemen's ladders on which human lives depend. At the 50-year rung the 1890 ladder of life accommodated fewer than half the persons who started the climb, while the 1930 ladder at the same point will hold almost three quarters of the starters.

III

In these pictures we see graphically how the prospects for the duration of the journey of life have been altered in the last fifty years or so, and for the better. The improvement has been great, and much credit is due to the medical and public health professions for the part they have played in bringing it about. But the pictures of the ladders do not make it entirely clear just how and wherein the improvement has been made. They give rather a broad general impression of the whole effect. In order to apprehend more clearly a very important, and often overlooked, point about this average improvement in the duration of the individual's life resort must be had to some other pictures, shown here as Fig. 2.

These are pictures of life ladders, too, but of only their upper parts. Suppose we consider what happened subsequently to 10,000 white males who got to the 40-year rung of the 1890 ladder in comparison with 10,000 who will get to the same rung of the 1930 ladder; and then suppose we make the same comparison between 10,000 who got to the 70-year rung of the 1890 ladder and an equal number at the same position on the 1930 ladder.

It is at once evident from Fig. 2 that the duration of the life journey after age 40 for those who have attained that age is, on the average, only slightly longer now than it was in 1890. According to the 1929–31 mortality experience 2.9 per cent. of all those (males) reaching 40 lived to reach 90 years of age. But the 1890 experience shows that 2.7 per cent., or almost as many relatively, did the same then. The gain in the half century for the 40-year-old boys is wholly insignificant in any practical point of view.

Fig. 2 further shows that those who attain the age of 70 now *actually do not do so well relatively,* on the average, in the way of further survival to still higher ages as did the stalwarts of 1890. At that time six hundred out of every 10,000 white males alive at age 70 lived on to 90 or more. Now, on the basis of the 1929–31 experience, only 563 manage this feat.

So it becomes plain that the important achievements in altering the shape of the ladder of life in the last 50 years, have been mainly in regard to the lower rungs. And it is chiefly the lowest or 10-year rung that has been improved. In 1890 only 72 per cent. of the boy babies starting got a foothold on that 10-year rung; now 91 per cent. do. This is splendid and must certainly be warmly approved of by every small boy. But there is extremely little in it to bring cheer to the man at 40 who would like to buy an annuity and look forward to gloating over the issuing insurance company as a nonagenarian.

In the common way of thinking longevity really means living past 80 years, and great human longevity means being a nonagenarian or centenarian. Progress in medicine and improvement in the public health have done little or nothing about enabling the individual to achieve such a goal, as the cold statistical facts about the order of human dying make abundantly clear. The *span* of human life has *not* been lengthened, and there is no present prospect that it soon will be. The *average duration* of life is all that has been altered, and that has been accomplished chiefly by giving more babies a fairer start in life's journey than they used to have. Because more of them get by the early and very difficult hurdles, absolutely more of them survive at later ages. But the terms of the bet that any individual man aged 70 to-day can safely say that he will be alive at 90 appear to be not quite as good as they were 50 years ago.

IV

What Everyman wants to know is whether there is not some sort of biological skullduggery that will, if he only knows what it is, enable him to make a surer and safer bet of this kind. There lies the real problem of the search for longevity. Why is it that some individuals alive at any given age will live thereafter longer than others? This is a biological question, and one of the most fundamental ones that science still has to worry over. In principle the duration of life of any individual is the net resultant of the interplay between his own innate biological make-up and the forces acting upon it, favorable or unfavorable, external and internal. This is a complete and sufficient logical statement of the case, but not so immediately useful as might be wished for the purpose of disappointing eager morticians. The practical searcher for individual longevity is not much interested in logical definitions. He is looking for more tangible help. What can be offered him?

One of the most often quoted things that Oliver Wendell Holmes ever said was that if one is setting out to achieve "three score years and twenty," the first thing to be done, "some years before birth, is to advertise for a couple of parents both belonging to long-lived families. Especially let the mother come of a race in which octogenarians and nonagenarians are very common phenomena." When this statement was made its only foundation was the general impression of a wise physician who spent his own life in a region where octogenarians and nonagenarians were common phenomena. Our practical searcher would like to know the extent or degree to which this impression has been supported by exact, quantitative investigation.

As the first and simplest approach to the question let us consider briefly the analysis of the pedigree of persons who have actually achieved great longevity.

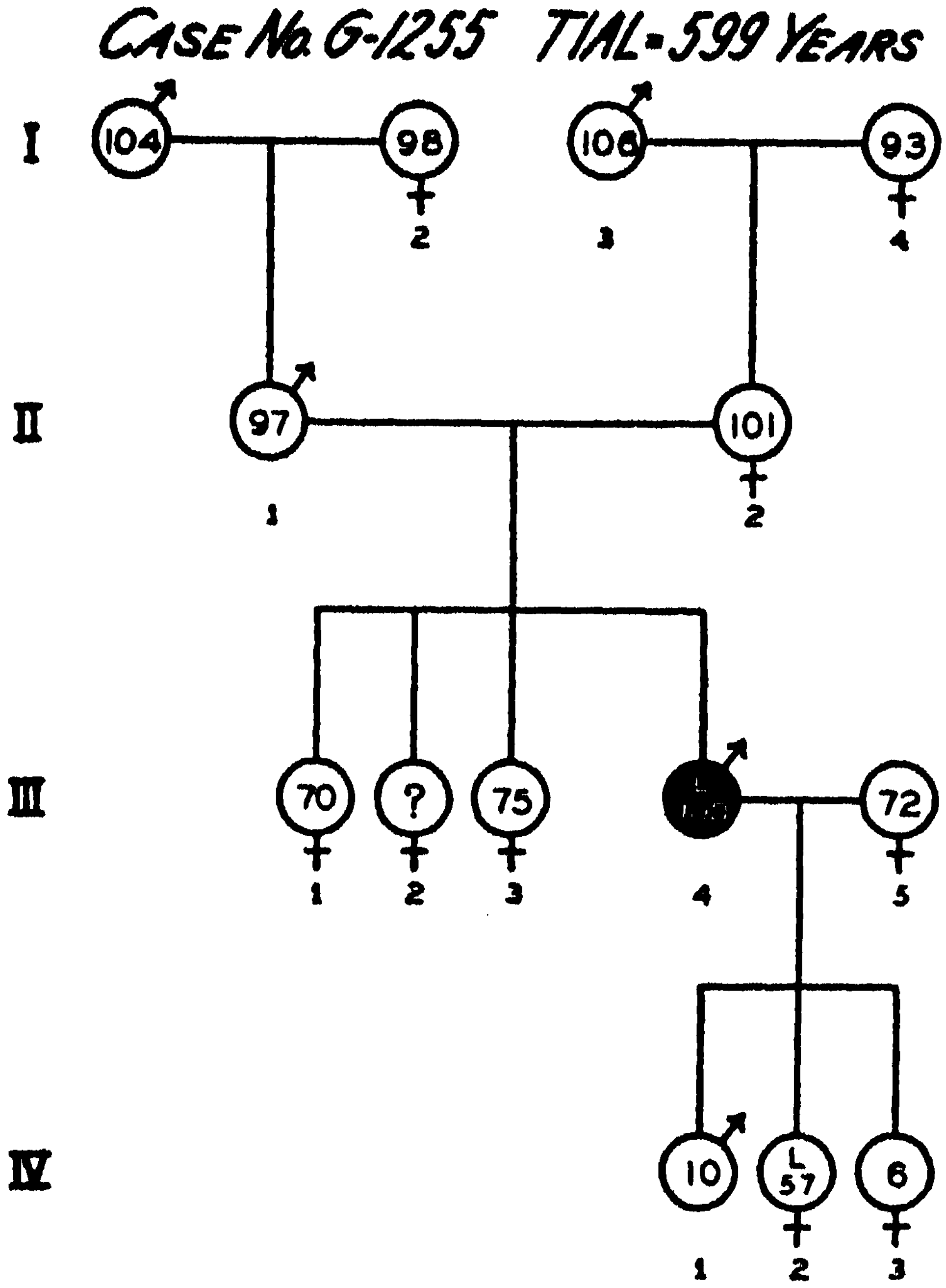


FIG. 3. PEDIGREE OF A CENTENARIAN. IN THIS PEDIGREE THE PERSON UNDER DISCUSSION (THE PROPOSITUS) IS INDICATED BY A SOLID SEX SIGN. FIGURES WITHIN THE CIRCLES OF THE SEX SIGNS INDICATE THE AGES AT DEATH IN YEARS, EXCEPT WHERE THERE IS AN L ABOVE THE AGE FIGURE, WHICH MEANS THAT THE PERSON WAS LIVING AT THE TIME OF RECORD, AND AT THE INDICATED AGE IN YEARS.

For many years we have been collecting data about persons actually living at ages of 90 years and above. The collection now includes more than 2,000 such persons, for whom the personal and family records may be accepted as reliable and trustworthy, after having been thoroughly and critically checked. Many more cases than this have gone through our hands, but have been rejected for scientific study because they did not meet the standards of proof that were set up.

In 1934 my daughter and I[4] published a rather extensive and detailed analysis of 365 of these cases of proven extreme longevity. For each of these cases the ages at death of the six immediate ancestors (two parents and four grandparents) were known and recorded, as well as a great many other things about the person and the ancestors. As an example, the pedigree of one of these highly longevous persons is shown in Fig. 3.

In this case the propositus (III, 4), living at the age of 100, was a Scottish seafaring man, who married and "settled down" at the age of 39. His immediate ancestry is very remarkable in point of longevity. His father (II, 1) and his maternal grandmother (I, 2) died as the result of accidents. His two children (IV, 1 and IV, 3) who died at early ages, met their end by drowning.

At the top of the chart the mysterious word TIAL is merely an abbreviation for "total immediate ancestral longevity," and is used to designate the sum of the ages at death of the parents and grandparents. Thus in the present case $104 + 98 + 106 + 93 + 97 + 101 = 599$ years. It is safe to say that few human beings have ever had an authentic TIAL number higher than this.

But how much lower are the TIALs of ordinary people, just "run-of-mine" folk who do not themselves live, on the average, longer than the average of the general population? To get an approximate answer to this question, and to have a group to compare with the highly longevous group of nonagenarians and centenarians we assembled, entirely at random so far as concerned their own ages, a group of 136 living persons all six of whose immediate ancestors (parents and grandparents) were dead at the time of observation, and for each of whom the age at death was known and recorded. This seems as fair a group for comparing TIALs with the longevous group as it is humanly possible to get. This comparison group had an average living age of 48.75 years, and contained 29 persons over 60 at the time of observation, 6 over 70, and 1 over 80. The average age of

[4] R. Pearl and Ruth D. Pearl, "The Ancestry of the Long-Lived." Baltimore and London: Johns Hopkins and Oxford University Presses, 1934. Pp. xiii + 168.

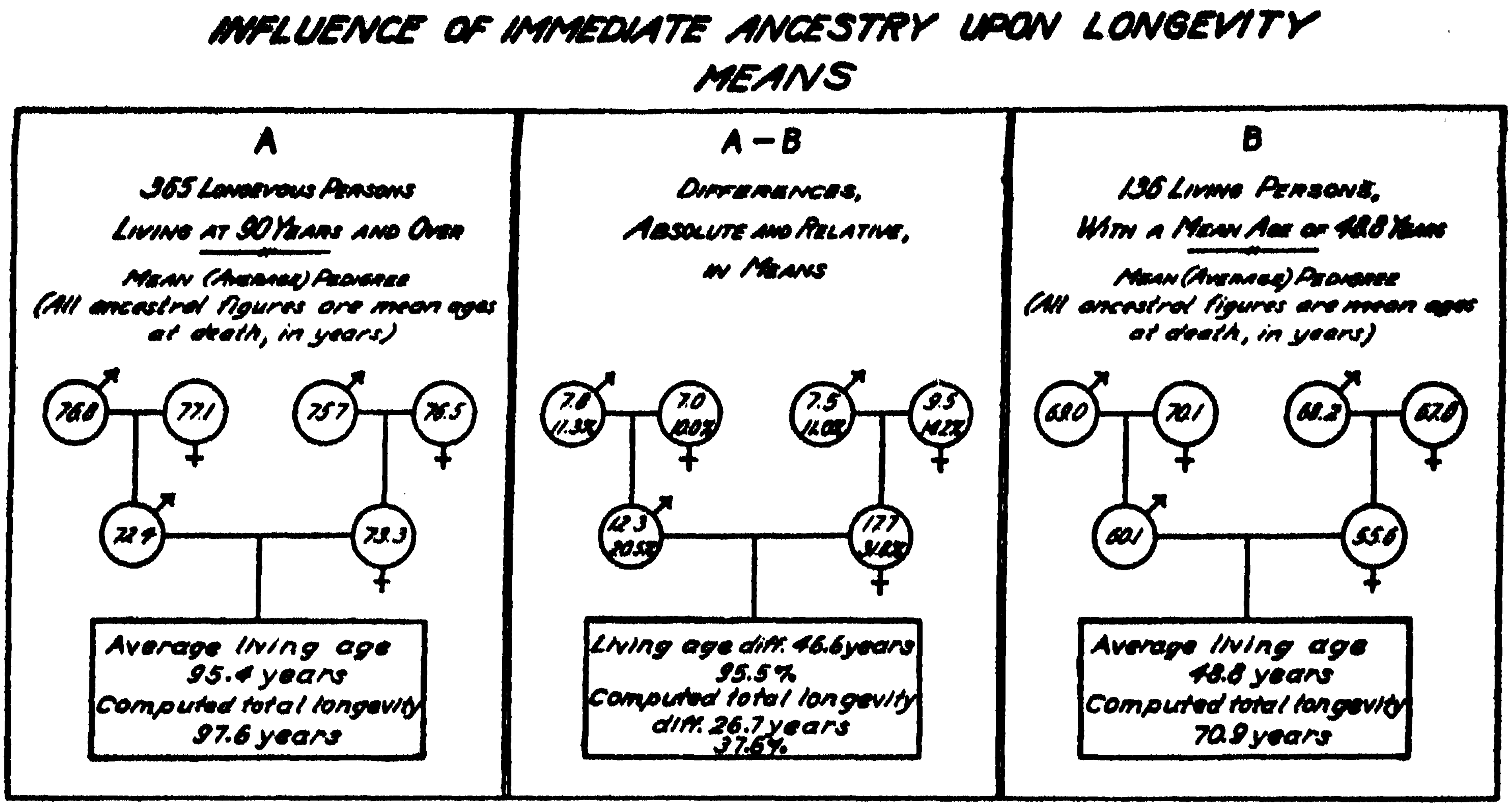


FIG. 4. INFLUENCE OF IMMEDIATE ANCESTORS UPON MEAN (AVERAGE) LONGEVITY.

the group was almost 16 years higher than that of the living white population of the United States in 1930.

How does the ancestral longevity of this group of ordinary folk compare with that of the elite group of extraordinary long-livers, the nonagenarians and centenarians? Fig. 4 gives the answer in graphic form.

From this diagram it is seen that, on the average, each single immediate ancestor, father, mother, grandfather or grandmother, of the extremely longevous persons of panel A on the left side, was longer-lived than the corresponding ancestor of the ordinary persons of panel B on the right side. Thus the fathers of the longevous died at the average age of 72.4 years. This was 12.3 years older, or over 20 per cent., than the average age of the fathers of the panel B folk at the right end of the chart. The central panel, A–B, gives the differences, in absolute numbers of years (upper figures in each sex sign) and as percentages of the panel B means, for each category of the six immediate ancestors. The "computed total longevity" figures for the propositi in the rectangles at the bottom are the resultants of adding to the mean number of years the A and B propositi had already lived at the time of observation the expectations of life proper to those ages, as given in a standard life table.

From this chart two results indubitably emerge regarding the influence of heredity upon longevity, namely:

(a) People who achieve extreme longevity have immediate ancestors (parents and grandparents) who are, on the average, definitely longer lived than the corresponding ancestors of the general run of the population. This is true without exception for each particular category of immediate ancestors.

(b) This hereditary influence promoting longevity is between two and three times as great relatively for parents as it is for grandparents, so far as the results of this investigation indicate.

It appears, then, that old Dr. Holmes was sound in his advice to select long-lived parents, and particularly long-lived mothers.

Let us now go a little deeper into the matter, by proceeding to examine more specifically how each of the *parents* of the extremely longevous persons was bred relative to longevity, as compared with the parents of the general run of folk. For the purposes of this inquiry let us

regard an individual who dies under 50 years of age as short-lived; one who dies between 50 and 69 years as average or mediocre in life duration, and one who dies at 70 or over as long-lived. These ranges in general agree fairly with common-sense opinion and usage. Fig. 5 shows the percentages of the fathers and mothers respectively that had (a) both of *their* parents long-lived (shown by the solid black portion of each bar); (b) one parent long-lived and the other mediocre or short-lived (shown by the cross-hatched portion of each bar); and (c) neither of their parents long-lived (shown by the white portion of each bar).

The picture presented by Fig. 5 is precise and striking. The nonagenarians and centenarians were produced by parents who were themselves bred out of wholly longevous parentage in more than half of all the cases observed—a markedly higher proportion than that shown by the parents of the general population sample. At the other end of the genetic scale the opposite is true. Fewer than half as many proportionally of the nonagenarians and centenarians as of persons generally were produced by parents who themselves had no longevous parentage whatever. It seems clear beyond question or doubt that breeding counted mightily in the production of these nonagenarians and centenarians.

Let us now turn to another method of approach, and a wholly different material, to get still another view of the importance of inheritance in the quest for longevity. Suppose one were to go out and collect entirely at random every single case possible to find of children dying before they were five years old—extremely short-lived human beings in fact, who were unable to get far in the pleasant business of living either because they were inherently bad biological eggs literally or figuratively, or because they never had a fair chance to live on account of a bad environment associated with parental poverty or ignorance or vice. Now suppose further that we followed the fathers of these poor creatures

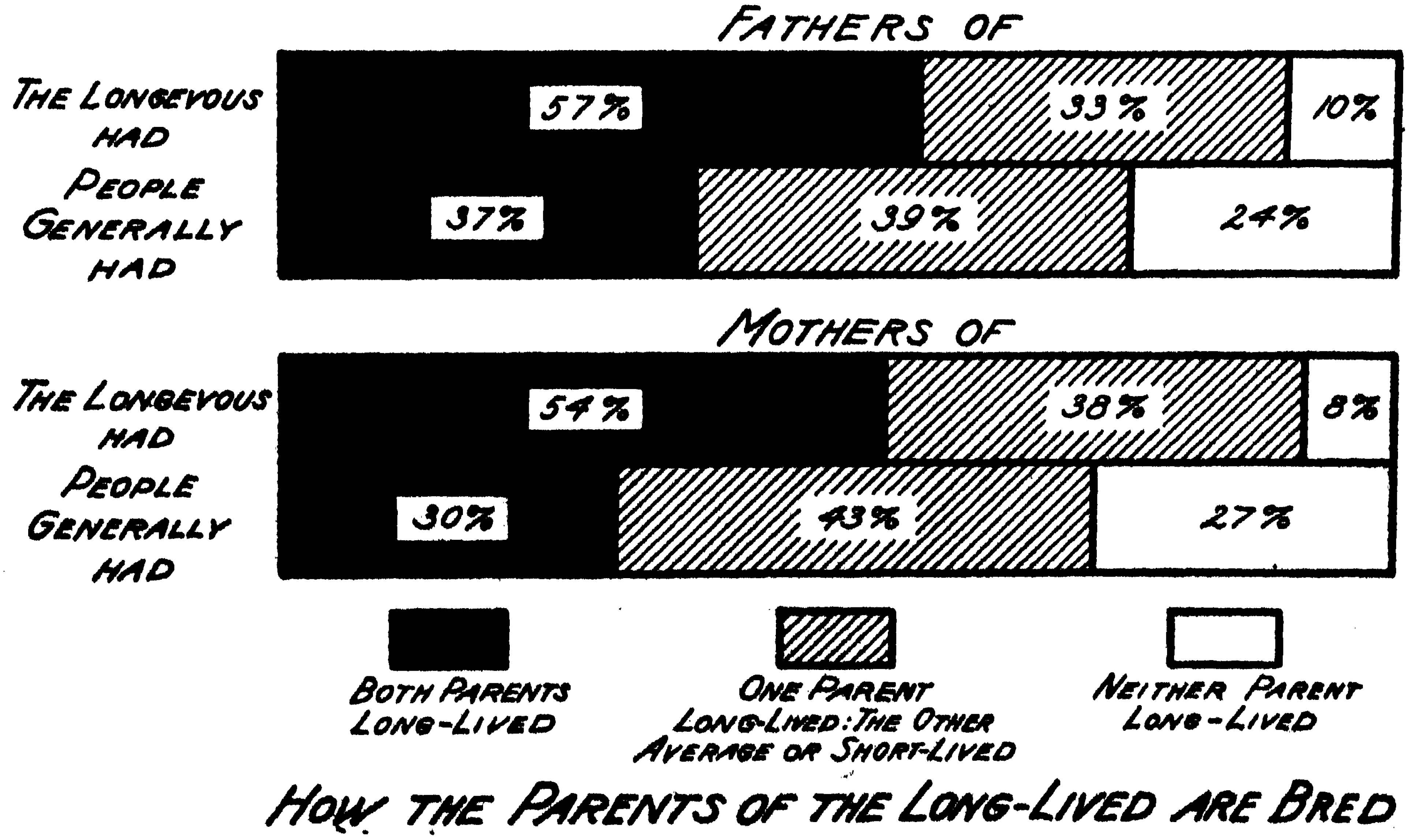


FIG. 5. THE PERCENTAGE DISTRIBUTIONS, RELATIVE TO THE NATURE OF THE PARENTAL MATINGS PRODUCING THEM, OF THE FATHERS AND OF THE MOTHERS OF (a) AN EXTREMELY LONGEVOUS GROUP (NONAGENARIANS AND CENTENARIANS), AND (b) A DEFINED SAMPLE OF PEOPLE GENERALLY.

along through their whole lives and set down in the record their ages at death when they (the fathers) finally died. It would then be possible to construct a life table for the category of *Fathers of Persons Dying under 5 Years of Age.* Having done all this, suppose we next did precisely the same thing for a group of fathers of persons who did not die until they were 80 years old or more—in other words, a group of old gaffers with demonstrated great powers of living, which powers may conceivably have arisen from their innately superior biological make-up or from great good luck combined with good sense in their choice of victuals and drink, or from always wearing their rubbers when it rained and woolies when it was cold, and so on through the entire list of precepts and superstitions thought to promote lon-

FIG. 6. EXPECTATION OF LIFE IN YEARS (MEAN-AFTER-LIFETIME) AT AGES 20, 40, 60, AND 80, OF FATHERS OF CHILDREN DYING (a) UNDER 5 YEARS OF AGE (SOLID BARS) AND (b) 80 AND OVER YEARS OF AGE (CROSS-HATCHED BARS).

FIG. 7. LIKE FIG. 6, BUT FOR MOTHERS.

gevity. When the data had been collected and the computations made we should then be in possession of a life table for the category of *Fathers of Persons Dying at 80 and Over Years of Age.*[5]

How will these two life tables compare with each other? Fig. 6 shows the answer so far as concerns the expectation of life (or average-after-lifetime) at four selected ages 20, 40, 60 and 80 years.

It is at once evident that, so far as concerns the present material involving well over a hundred thousand life years' exposure to risk, the long-lived children had fathers who were much longer-lived than the fathers of short-lived children. The figures at the tops of the bars give the expectations of life at the ages indi-

[5] For details regarding the construction of these and the life tables to be discussed below see R. Pearl, "Studies on Human Longevity. IV. The Inheritance of Longevity." *Human Biology*, 3: 245–269, 1931.

cated at the bottoms of the bars. Thus the average *total* duration of life from birth of the fathers of children dying at ages of 80 and over was $58.5 + 20 = 78.5$ years.

Corresponding life tables for mothers tell the same sort of story, as is shown in Fig. 7.

The *relative* excess in life duration of the parents of long-lived as compared with short-lived children is very considerable. Thus the mean-after-lifetime of *fathers* of children dying (or living) at ages of 80 and over is about 26 per cent. greater at age 20; 43 per cent. greater at age 40; 75 per cent. greater at age 60; and 58 per cent. greater at age 80, than the mean-after-lifetime at the same ages of fathers of children dying under 5. The corresponding excesses

FIG. 8. EXPECTATION OF LIFE IN YEARS (MEAN-AFTER-LIFETIME) AT AGES 0 (BIRTH), 20, 40, 60, AND 80 YEARS, OF THE *sons* OF FATHERS DYING (a) UNDER 50 YEARS OF AGE (SOLID BARS); (b) BETWEEN 50 AND 79 YEARS OF AGE (DOUBLE CROSS-HATCHED BARS); AND (c) 80 AND OVER YEARS OF AGE (SINGLE CROSS-HATCHED BARS).

in expectation of life of mothers are 27 per cent. at age 20; 27 per cent. at age 40; 36 per cent. at age 60; and 23 per cent. at age 80. The suggestion plainly is that right away through the whole life span the parents of very long-lived children appear to be persons of superior biological constitution, as evidenced by their ability to keep on living.

What now of the situation turned the other way about? How will the respective life tables compare if we construct them for the *children* of short-lived, moderately long-lived and very long-lived parents? This we have done for *sons* as a class, with the results shown in Fig. 8.

Plainly the results of these life tables for sons confirm the conclusions derived from those for fathers and mothers that have just been examined. As we pass upwards through the three broad classes of paternal longevity the expectation of life of the sons at all ages steadily rises. The expectation of life of the sons of short-lived fathers is less than that of the sons of moderately longevous fathers, and still less than that of the sons of extremely long-lived fathers. Thus at age 60 the sons of very long-lived fathers (80 and over) have a further average expectation of life nearly 40 per cent. greater than that of sons whose fathers died before age 50.

It seems unnecessary to present further evidence to demonstrate the great significance of genetic factors in determining individual differences in the length of human life. The inherited biological constitution of each individual human being—his or her genetically determined inherent viability—is beyond question one of the major determiners of the probable length of that person's life. It is not, however, the sole or absolute determiner. Obviously any one can behave in such a way that his or her genetic birthright in longevity is prevented from coming to its full expression. Prematurely taking one's own life is per-

haps the most nearly perfect example. On the other hand, the general effect of public health and sanitary measures is to create and promote such conditions of living as will permit the greatest possible number of people to bring as nearly as possible to complete realization and expression the inherent viability with which they have been genetically endowed. In the changing shapes of the Ladder of Life shown earlier it has been seen how great the progress has been in this respect for the earlier years, and how little for the later years of the life span. This suggests, in the light of the evidence regarding the inheritance factors in longevity, two conclusions that may be of considerable significance. The first is that there exist broad classes of human beings differentiated from each other in their innate endowments in respect of inherent viability, one class being short and the other being long of this important quality. The second suggested conclusion is that improving the environmental circumstances of living can do, and has done, a great deal more for the first class than for the second in the way of increased longevity. It appears probable that there is now, and always has been in past ages, a class of human beings by nature so abundantly endowed in the matter of viability that they have always, as a statistical group, so nearly realized their innate potential viability regardless of environmental circumstances as to be not significantly affected in average duration of life by any general improvement of those circumstances.

Detailed study of the life histories of extremely longevous persons, such as has been possible with our collection of such records, strongly suggests that nonagenarians and centenarians are biologically differentiated from the general run of mankind in just the manner postulated for the second biological class just described. As a group nonagenarians and centenarians have definitely *not* led protected lives in specially favorable environmental circumstances; nor have they had better medical advice or care than the generality of men; nor, finally have they conducted their lives more hygienically than others, according to the rules and precepts generally regarded as conducive to long life. On the contrary they have just lived, but lived a much longer time than most.

This view of the matter is further supported by an analysis of the causes of death of nonagenarians, made some years ago on the basis of the official records of the Census Bureau.[6] That analysis led to the conclusion that nonagenarians are a selected lot of people. They are the ultimate survivors after all the rest of mankind has gone, unable to meet the vicissitudes of life and keep on living. Nonagenarians come to be such because they have organically superior constitutions, resistant to infections, soundly organized to function efficiently as a whole organism and keep on doing it for a very long time. Observations on mortality at ages indicate that throughout life infections and other harmful environmental forces are, on the whole, tending to take off the weaker and leave the stronger. Medical knowledge and skill, improved sanitation and better conditions of life generally have been and are, able to prevent an increasingly larger amount of what may be called premature mortality before age 50, let us say. Especially have these agencies been able to reduce the lethal effects of infections, or at least to postpone to a later part of the life span their fatal action. But ultimately there is left a group of extremely old people, for whom on the whole infections have no particular terrors. In all the early part of their lives they have been able successfully to resist infections, and to a remarkable degree still are in extreme old age.

[6] R. Pearl and T. Raenkham, "Studies on Human Longevity. V. Constitutional Factors in Mortality at Advanced Ages." *Human Biology*, Vol. 4, pp. 80–118, 1932.

These people eventually die, to be sure. But a great many of them die, not because the noxious forces of the environment kill them, but because their vital machinery literally breaks down, and particularly that important part of it—the circulatory system.

V

Evidence has been presented indicating that genetic factors are important in determining individual longevity. It has further been suggested that these genetic influences manifest themselves in relation to longevity primarily through the general biological constitution of the individual, so far as can be judged in the basis of present knowledge regarding this complex and difficult problem.

There will now be presented for the first time, in necessarily condensed form, some results of an investigation now in progress that appear to throw additional light on the problem of constitution in relation to longevity. The problem attacked may be put in this way: Suppose that one were able to make fairly thorough and complete studies, medical, anthropometric and genetic, of adult persons in a state of health at the time of observation, then follow them individually till they died, and then finally determine and record the causes of their deaths individually. Would it then be possible to isolate and differentiate any characteristics exhibited at the time of original observation years before, from which could have been predicted *then* who were destined to be the long-lived and who the short-lived, had the original observer been as wise before the event as afterwards? In other words, is it possible by any sort of examination or study of healthy adult individuals to predict which ones are destined for a long subsequent life and which will exhibit no marked powers of further survival?

At the expense of considerable time and labor records have been collected upon this question, and some of them have been analyzed. In particular we have studied rather thoroughly 386 white males from this point of view. These individuals were originally observed and recorded at ages ranging from 20 to over 60 years; 193 of them proved in the event to be long-lived, in the sense that each one of them outlived in greater or smaller degree the expectation of life (mean-after-lifetime) for his age when observed, according to Dublin and Lotka's 1929–31 life tables already referred to above. All white males in our records fulfilling this condition of survivorship greater than that expected from the life table were taken for study without any selection. Then as a partner for each one of these 193 long-lived males there was taken from the record a white male of the same decade of age, who died *before* reaching the expected degree of survivorship proper to his age as set forth in the Dublin and Lotka life tables. All these 386 persons died in the end of some form of cardiovascular disease—that is of heart disease in one or another of its forms or of some affection of the arteries or veins.

So then in sum, what we have are two groups of white males of the same age distribution and in a state of health at the time of observation, all of whom died of diseases characterized by structural or functional breakdown or inadequacy of the circulatory system. One of these groups was definitely longer-lived than the average of American men at the present time, while the other group was definitely shorter-lived than the average. In what respects, if any, did the two groups differ from one another before either displayed any discernible evidence of cardiovascular disease? Table 1 and Fig. 9 give the more important aspects of the answer to this question.

Considering Part A of the table it is seen that while the two groups were substantially *identical* in average age at observation (approximately 40 years) the

long-lived group lived thereafter more than 26 years or over 52 per cent. *longer* than did the short-lived group. The actual survival of the first group was 123 per cent. of life table expectation, while that of the second group was only about 35 per cent. of life table expectation.

At the time of observation the average pulse rate per minute was, by an absolutely small but statistically significant amount *slower* in those destined for long life than in those who were to live less than a third as long a time. Furthermore the long-lived group exhibited at observation an average systolic blood pressure slightly over 2 per cent. *higher* than did the short-lived group, a difference that is, however, statistically insignificant. The average blood pressure in both groups, it will be noted, was well within what is regarded as the clinically normal range for persons of an average age of about 40 years. But the number in the long-lived group for which blood pressure readings were available was very small (27 cases only), so that altogether the findings relative to blood pressure depend upon only 54 individuals in total. A satisfactory appraisal of the situation relative to blood pressure differences between long-lived and short-lived groups will have to wait on the slow accumulation of additional data.

In physical characteristics of the body (Part B) the two groups were of substantially *identical* average stature, but

TABLE 1

CONSTITUTIONAL DIFFERENCES BETWEEN LONG-LIVED AND SHORT-LIVED WHITE MALES WHEN OBSERVED IN A STATE OF HEALTH PRIOR TO THE ONSET OF THE CARDIOVASCULAR DISEASES THAT EVENTUALLY LED TO DEATH

Part A. Age and physiological characteristics

Cause of death, group and differences	Mean (average) value of characteristic					
	Age at observation (yrs.)	Age at death (yrs.)	Actual survival (yrs.)	Percentage of expected survival (yrs.)	Pulse rate (per minute)	Systolic blood pressure
Long-lived ($N = 193$) ..	40.09	76.59	36.49	123.45	73.45	133.89
Short-lived ($N = 193$) ..	39.56	50.27	10.69	35.45	74.62	131.22
Difference	+0.53 ± .71	+26.32 ± .50	+25.80 ± .63	....	−1.17 ± .29	+2.67 ± 1.74
Difference as per cent. of short-lived mean..	+1.34	+52.36	+241.35	....	−1.57	+2.03

Part B. Somatological characteristics

Cause of death, group and differences	Mean (average) value of characteristic						
	Stature (cm)	Body weight (kg)	Body weight ratio (kg)	Chest girth at expiration (cm)	Chest expansion (cm)	Umbilical girth (cm)	Habitus index (%)
Long-lived ($N = 193$) ..	173.80	70.27	4.04	86.62	9.06	85.05	98.77
Short-lived ($N = 193$) ..	174.09	74.56	4.28	89.51	9.55	86.47	101.09
Difference	−0.29 ± .43	−4.29 ± .68	−0.24	−2.89 ± .48	−0.47 ± .21	−1.42 ± .62	−2.32
Difference as per cent. of short-lived mean	−0.17	−5.75	−5.60	−3.23	−5.13	−1.64	....

Part C. Genetic data

Cause of death, group and differences	Mean (average) value of characteristic					
	Percentage of parents living at time of observation	Percentage of sibship living at time of observation	Percentage of total sibship dying in infancy	Per cent. of all parents and sibs dead of cardiovascular diseases	Per cent. of all parents and sibs dead of respiratory diseases	Per cent. of all parents and sibs dead of diseases of alimentary tract
Long-lived ($N = 193$) ..	48.96	73.71	9.15	3.00	5.33	3.43
Short-lived ($N = 193$) ..	41.58	80.56	5.72	4.92	4.37	2.98
Difference	+7.38	−6.84	+3.43	−1.92	+0.96	+0.45

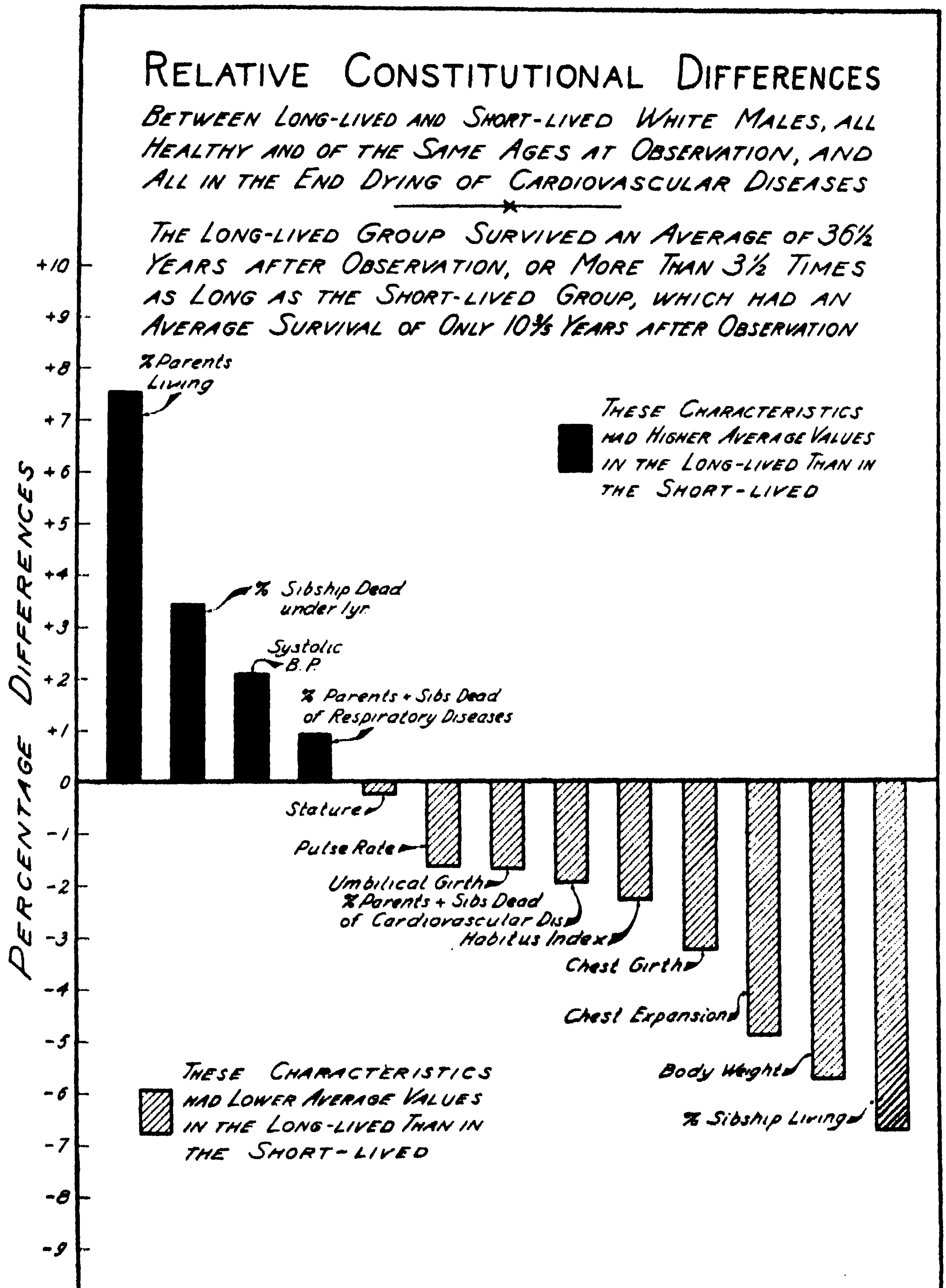


FIG. 9. SOME RELATIVE DIFFERENCES IN CONSTITUTION BETWEEN LONG-LIVED AND SHORT-LIVED WHITE MALES. FOR FURTHER DESCRIPTION SEE TEXT.

the long-lived group *weighed*, on the average, nearly 6 per cent. *less* than the short-lived group, again a statistically significant difference. Furthermore the long-lived averaged to be *smaller* in chest girth (at expiration) and in girth at the level of the navel (umbilical girth) than the short-lived. Also, as shown by the habitus index,[7] the long-lived group on the average was *less* of the pyknic type in body build than the short-lived group —in other words the long-livers tended to be more like Don Quixote and the short-livers more like Sancho Panza in their bodily structure.

The long-lived group had over 7 per cent. *more*, on the average, of their parents alive at the time of observation than did the short-lived group, indicating a sounder inheritance in respect of longevity. On the other hand, *fewer* of the brothers and sisters of the long-lived, on the average, were still living when the observations were made, than was the case with the short-lived. This suggests that natural selection had operated more stringently in the sibships containing the long-lived persons, an interpretation that is supported by the higher infant mortality rate that had manifested itself in the sibships of the long-lived. Finally, and more specifically from the genetic side, the long-lived group, had *fewer* proportionately of their parents and sibs dead of cardiovascular diseases at the time of observation than did the short-lived.

Fig. 9 sums up graphically some of the results of this constitutional study.

In general it appears, so far as may be judged from the present sample, that there is a definite possibility that long-lived persons as a group can be statistically differentiated from short-lived persons in respect of a number of structural, physiological, and genetic characteristics, long before they are going to die and while they are still in sound health. It would be unwise to generalize much further than this at present. More work needs to be done, and we propose to continue doing it just as rapidly and extensively as can be managed. It is a laborious and expensive sort of research, and the resources available to us for its support are so meager that progress is distressingly slow. But the results already achieved seem clearly to indicate that we have opened up here a line of approach to the problems of human longevity that gives promise of eventually yielding results of considerable significance, both theoretical and practical. We have made similar analyses to the one here presented for two smaller groups of long-lived and short-lived persons dying respectively of cancer and pneumonia, with extremely suggestive results; but the cases available are still too small to warrant even preliminary publication at present.

VI

Up to this point the discussion has ben almost entirely of the innate, constitutional elements concerned in the determination of individual life duration. It is now time that some attention be devoted to the environmental aspects of the picture. Here is where the eager searcher for longevity finds his greatest interest. For while he will admit that in an academic or philosophical point of view it is doubtless desirable to know as much as possible about the hereditary and constitutional factors influencing life duration, still these are after all not matters about which he can do much in the way of promoting his own personal longevity. "Choosing one's parents" is a sufficiently amusing figure of speech, but really nothing much more than that.

[7] Habitus index $= \dfrac{100 \text{ (Chest girth at expiration + Umbilical girth)}}{\text{Stature}}$

This somatological index, which appears not to have been used hitherto, is proving to be a very useful one in classifying variation in bodily habitus (Kretschmerian typology). The asthenic type of body build leads to a relatively low index, and the pyknic type to a relatively high one. It is intended to publish soon in another place a detailed discussion of this index.

What our searcher really wants is to be able to do something effective right here and now about a matter of such transcendent personal concern. He would like to be authoritatively told how he should conduct his life so to live long. Still better he would like to be provided with some pleasant pill or potion guaranteed to keep him going until he reaches ninety at least, without any bother about what he eats or drinks in the meantime, or whether he bundles up well when he goes out in the cold. Best of all he would like to be supplied with some of the authentic juice that flows from the Fountain of Perpetual Youth. Since mankind started making literary records of his thoughts and aspirations the search for that elusive spring has been earnestly prosecuted. Many people have figured out just what it would look like when it was found. One of the most charming and delightful of its many portrayals serves as the frontispiece of a rather rare book that is one of the gems of an extensive collection of tracts and treatises dealing with longevity down through the ages. The title page of this book is shown in facsimile in Fig. 10. The frontispiece depicting the Fountain of Perpetual Youth, with its surrounding landscape is shown in Fig. 11.

HISTOIRE
DES PERSONNES
QUI ONT VECU
PLUSIEURS SIECLES,
ET QUI ONT RAJEUNI:
AVEC LE SECRET
DU RAJEUNISSEMENT,
Tiré d'Arnauld de Villeneuve.
Et des Régles pour ſe conſerver en ſanté, & pour parvenir à un grand âge.
Par Mr. DE LONGEVILLE HARCOVET.

A PARIS,
Chez la Veuve CARPENTIER, & LAURENT LE COMTE. 1716.

AVEC APPROBATION ET PRIVILEGE.

Se vend A BRUXELLES,
Chez JEAN LEONARD, Libraire & Imprimeur rue de la Cour.

FIG. 10. FACSIMILE OF THE TITLE PAGE OF HARCOUET'S *Histoire*.

FIG. 11. FACSIMILE OF THE FRONTISPIECE OF HARCOUET'S *Histoire*, DEPICTING THE FOUNTAIN OF YOUTH. ORIGINAL SIZE OF ENGRAVED AREA 110 × 66 MM.

One notes the triumphant and smug satisfaction with which his conductor is telling the weary and sceptical old physician in the lower left foreground, who may be Aesculapius himself: "There, you doubting old fuddy-duddy, I said it was here, and *here it is!* See for yourself!" In the right foreground is evident the almost obscene eagerness of the old boys just arrived to guzzle the precious fluid gushing from the fountain, while the bloated saurian leers up at them and gets his share. In the distant background we get a glimpse of the garden in which so much of humanity as was there remained perpetually youthful, until the lady unfortunately committed a technical error. The fauna of the environs of the fountain is characteristically reptilian. Of the four Orders of the Class Reptilia three are represented—the *Loricata* (Crocodiles and Alligators), the *Chelonia* (Tortoises and Turtles), and the *Squamata* (Lizards and Snakes). The only Order omitted is the *Rhyncocephalia*, which contains only one form, the famous *Tuatera* found in the islands of Cook Strait, New Zealand. This seems an excusable omission, because New Zealand has always been so far away from the center of things. It will also be noted that an elephant is emerging from the trees in the background. This is to round out the lesson of the picture as a whole; because, of all mammals except man, the elephant is the longest lived. The Reptilia of course have always been noted for longevity. The banner borne by the two Rocs at the top of the picture is an anachronism, plainly put in as a sop to conservative respectability. For if we really had access to the Fountain of Perpetual Youth who would worry about health?

Unfortunately it has proved impossible to get a supply of water from the Fountain of Youth to distribute on this occasion. Lacking this the best that can be done is to discuss some of the environmental factors that have been thought to be, or in fact are, importantly concerned in the achievement of longevity. Only those will be chosen for discussion about which there exists definite scientific evidence, pertinent to the point at issue.

Of all such factors the use of alcoholic beverages has probably been most discussed. The problem of the effect of such usage upon longevity has excited violent and unreasoning prejudice on the part of large numbers of people. They contend that alcohol always and everywhere shortens the lives of its users. There is much evidence, experimental, statistical and actuarial that this is not a universally valid generalization. This evidence does not make the slightest impression upon those who believe, that is to say *have faith*, that the generalization is valid. So an *impasse* results. So far as I am aware there has been constructed only once a set of life tables for classes of persons homogeneous in respect of

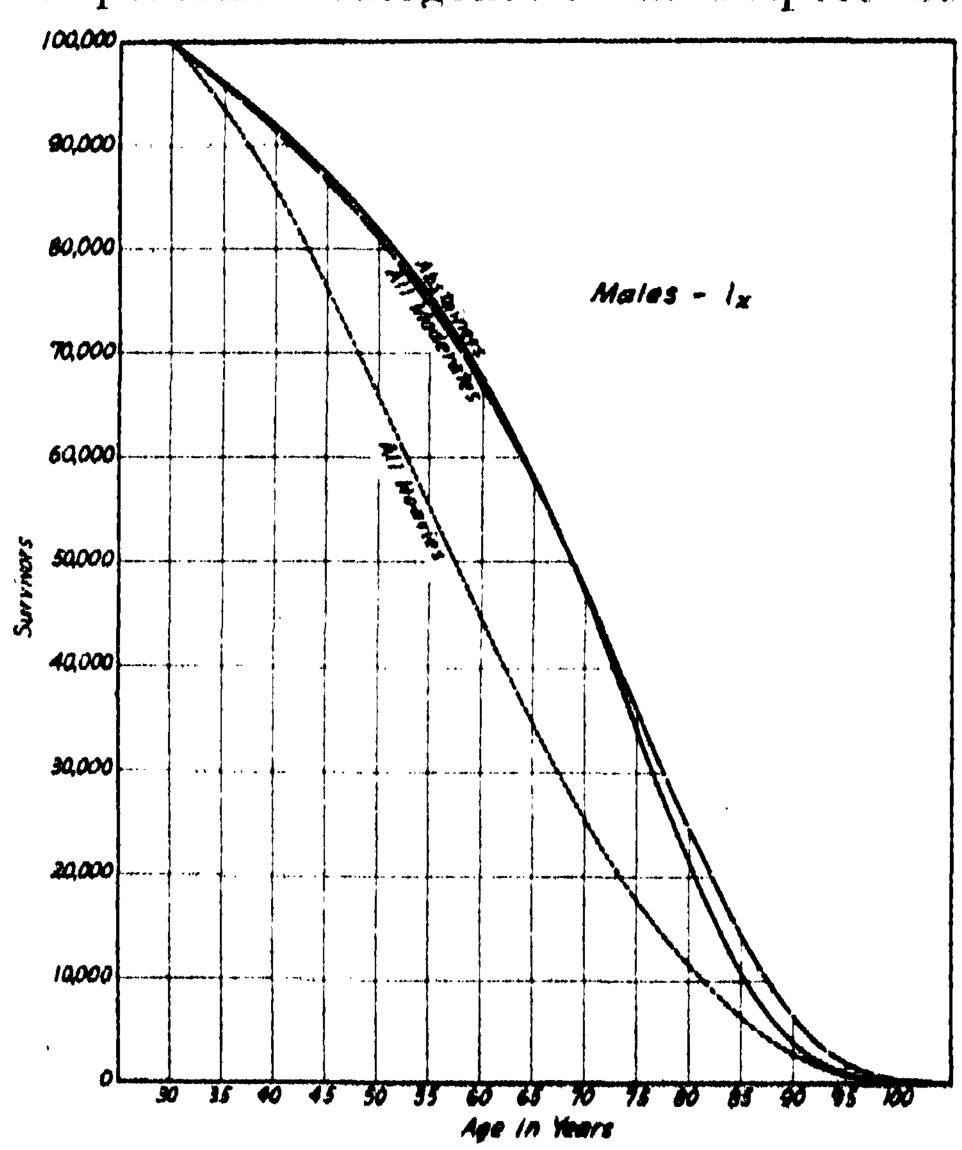


FIG. 12. THE NUMBER OF SURVIVING MALES OUT OF 100,000 STARTING TOGETHER AT AGE 30, IN THREE DRINKING CATEGORIES: (a) ABSTAINERS (SOLID LINE), (b) MODERATE DRINKERS (DASH LINE), AND (c) HEAVY DRINKERS (DOT LINE).

TABLE 2

THE NUMBER OF SURVIVORS, AT 5-YEAR AGE INTERVALS STARTING AT AGE 30, OF (a) 100,000 WHITE MALES WHO WERE NON-USERS OF TOBACCO; (b) 100,000 WHO WERE MODERATE SMOKERS BUT DID NOT CHEW TOBACCO OR TAKE SNUFF; AND (c) 100,000 WHO WERE HEAVY SMOKERS BUT DID NOT CHEW OR TAKE SNUFF

Age	Number of Survivors l_x						
	Non-users	Moderate	Heavy	Age	Non-users	Moderate	Heavy
30	100,000	100,000	100,000	65	57,018	52,082	38,328
35	95,883	95,804	90,943	70	45,919	41,431	30,393
40	91,546	90,883	81,191	75	33,767	30,455	22,338
45	86,730	85,129	71,665	80	21,737	19,945	14,494
50	81,160	78,436	62,699	85	11,597	10,987	7,865
55	74,538	70,712	54,277	90	4,573	4,686	3,292
60	66,564	61,911	46,226	95	1,320	1,366	938

their habits relative to alcoholic indulgence, and based upon critically adequate and pertinent data collected at first hand.[8] Those life tables lead to the general conclusion graphically depicted in Fig. 12.

That conclusion is that moderate drinking does not significantly shorten life when compared with total abstention from alcohol, while heavy drinking does seriously diminish the length of life.

These results have been accepted by some, and rejected by other equally sincere, equally honest and intelligent groups of people, who however differ widely in their emotions and sentiments regarding the use of alcohol by man as a beverage. Nothing further can be done about the case. Presumably each one of the present audience is already a component of one or the other of these two groups.

Let us turn next to the use of tobacco and longevity. This usage is probably, along with that of alcohol, one of the most wide-spread amongst humanity relative to substances or materials that are not, in themselves, necessary to the maintenance of life as is food. Is the smoking of tobacco associated statistically with any impairment of the normal expectation of life, or with an improvement of it, or is there no measurable association one way or the other? This question, too, has excited controversy, though not so violent as that over alcohol. It is the intention to present now for the first time a small part of the hitherto unpublished results of an investigation of this problem.[9] This investigation, like the preceding one on alcohol, has been carried out with painstaking care, and such critical acumen, judgment and fairness as my collaborators and I possess. The data were collected at first hand *ad hoc*. Their accuracy as to the relative degree of habitual usage of tobacco, and as to the ages of the living at risk, and of the dead at death can be guaranteed. The figures to be presented deal only with white males, and with the usage of tobacco by smoking. The material falls into three categories, as follows: *non-users* of tobacco, of whom there were 2,094; *moderate smokers*, of whom there were 2,814; and *heavy smokers*, of whom there were 1,905. In other words, the results presented here are based upon the observation of 6,813 men in total. These are not large numbers from an actuarial point of view, but are sufficient to be probably indicative of the trends that would be shown by more ample material. Naturally the men included in the observation were an unselected lot except as to their tobacco habits. That is to say they were at random, and then all sorted into categories relative to tobacco usage. For each of the three categories of tobacco usage complete life tables from

8 R. Pearl, "Alcohol and Longevity." New York: Alfred A. Knopf, 1926. Pp. xii + 273.

9 Since this lecture was delivered there has been published a further account of these life tables. R. Pearl, "Tobacco Smoking and Longevity," *Science*, 87: 216–217, 1938.

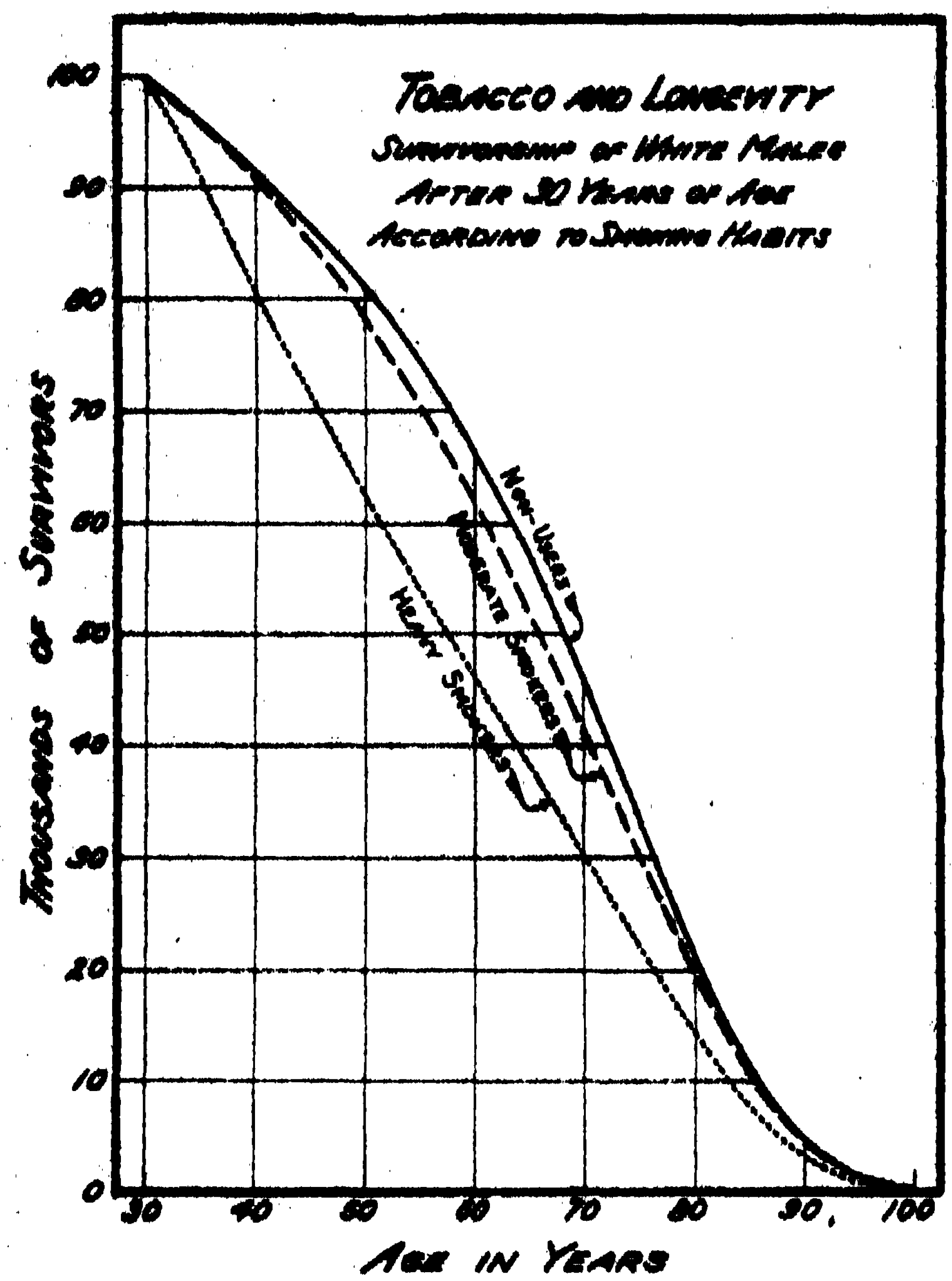


FIG. 13. THE SURVIVORSHIP LINES OF LIFE TABLES FOR WHITE MALES FALLING INTO THREE CATEGORIES RELATIVE TO THE USAGE OF TOBACCO. A. NON-USERS (SOLID LINE); B. MODERATE SMOKERS (DASH LINE); C. HEAVY SMOKERS (DOT LINE).

age 30 on to the end of the life span have been constructed.

It is intended to publish eventually in detail the results of this investigation. Here there can be presented only a condensed table, which gives the survivorship (l_x) values, at 5-year intervals from age 30 on, for the three usage categories.

The figures of Table 2 are shown graphically in Fig. 13.

The net result is obvious. In this group of nearly 7,000 men the smoking of tobacco was associated definitely with an impairment of life duration, and the amount or degree of this impairment increased as the habitual amount of smoking increased. The contrast between the life tables relative to the implied effects upon longevity of moderate smoking, on the one hand, and the moderate use of alcoholic beverages, on the other hand, is very striking. The moderate smokers in this material are definitely shorter lived than the total abstainers from tobacco; the moderate drinkers are not significantly worse or better off in respect of longevity than the total abstainers from alcohol. Heavy indulgence in either tobacco or alcohol is associated with a very poor life table, but the life table for heavy smokers is definitely worse than that for heavy drinkers up to about age 60. Thereafter to the end of the life span the heavy smokers do a relatively better job of surviving than the heavy drinkers. But neither group has anything to boast about in the matter of longevity.

The third environmental problem to be discussed may be put in this way: Does hard physical labor shorten life? The answer to this question is shown graphically in Figs. 14 and 15.

The data[10] on which Figs. 14 and 15 are based come from English occupational mortality statistics which are as accurate and comprehensive as any in existence. The results indicate that there is a direct and definite relation between the magnitude of the age specific death rates from age 40 to 45 on, and the average expenditure of physical energy in occupation, *after* accidental deaths and deaths directly resulting from the hazards of each of the several occupations have been deducted. This relation is of the sort that associates high mortality with hard physical labor. The relationship prevails whether the labor is performed chiefly indoors or chiefly outdoors. It is not primarily to be attributed to the general environmental factors connoted by social class distinctions, which are themselves correlated with average energy expenditure in occupation. Before age 40 is attained, it makes no difference in the rate of mor-

[10] See R. Pearl, "Studies in Human Longevity." Baltimore: Williams and Wilkins, 1924, Chapter XI, for a detailed account of this study.

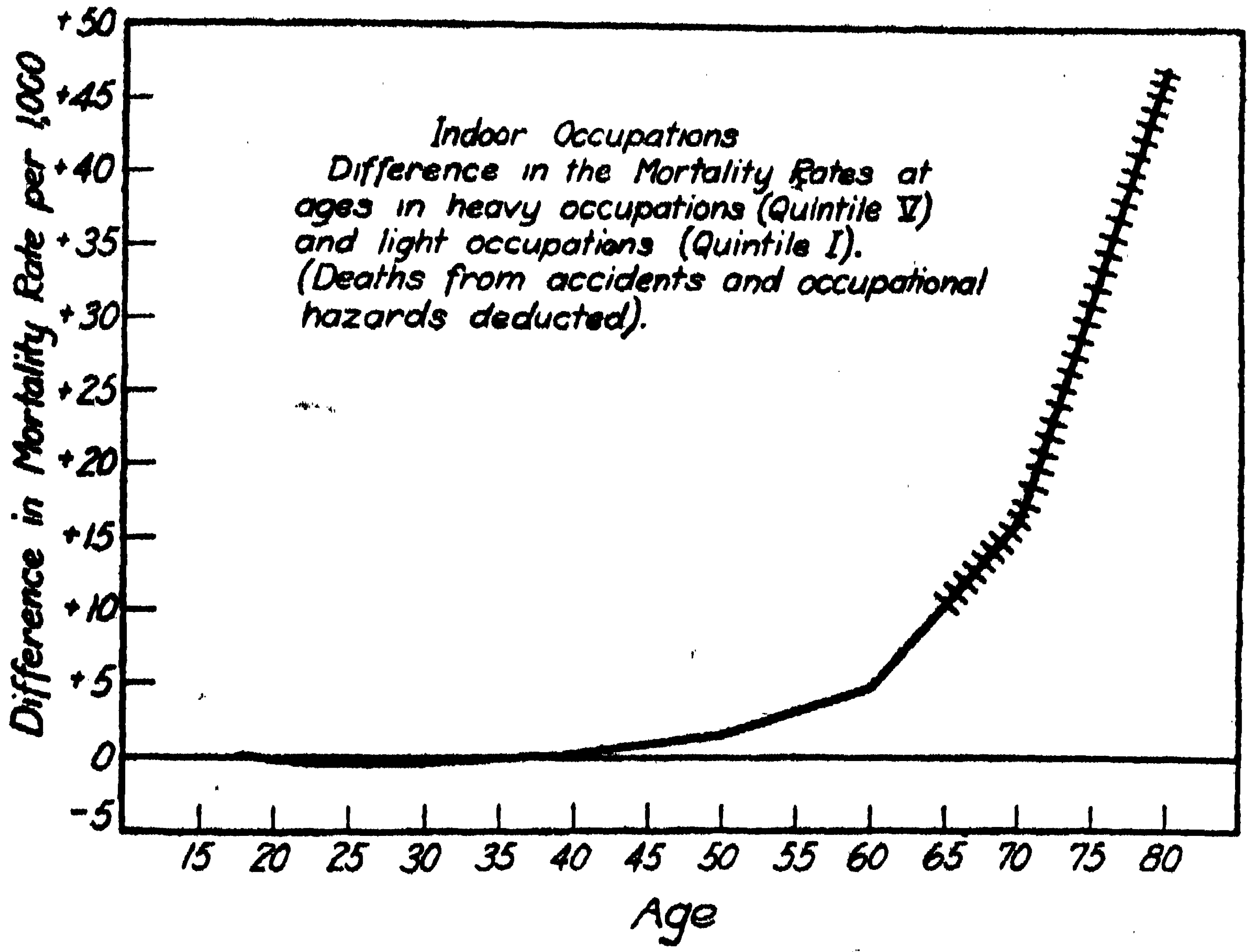


FIG. 14. DIFFERENCE BETWEEN (a) INDOOR OCCUPATIONS INVOLVING THE GREATEST AMOUNT OF PHYSICAL EXERTION (QUINTILE V) AND (b) INDOOR OCCUPATIONS INVOLVING THE LEAST AMOUNT OF PHYSICAL EXERTION (QUINTILE I), IN RESPECT OF AGE SPECIFIC MORTALITY RATES. THE LINE IS CROSSED FROM AGE 65 ON TO INDICATE THAT ITS TRUE POSITION IS UNCERTAIN AT ADVANCED AGES, BECAUSE OF THE MEAGERNESS OF THE DATA AVAILABLE.

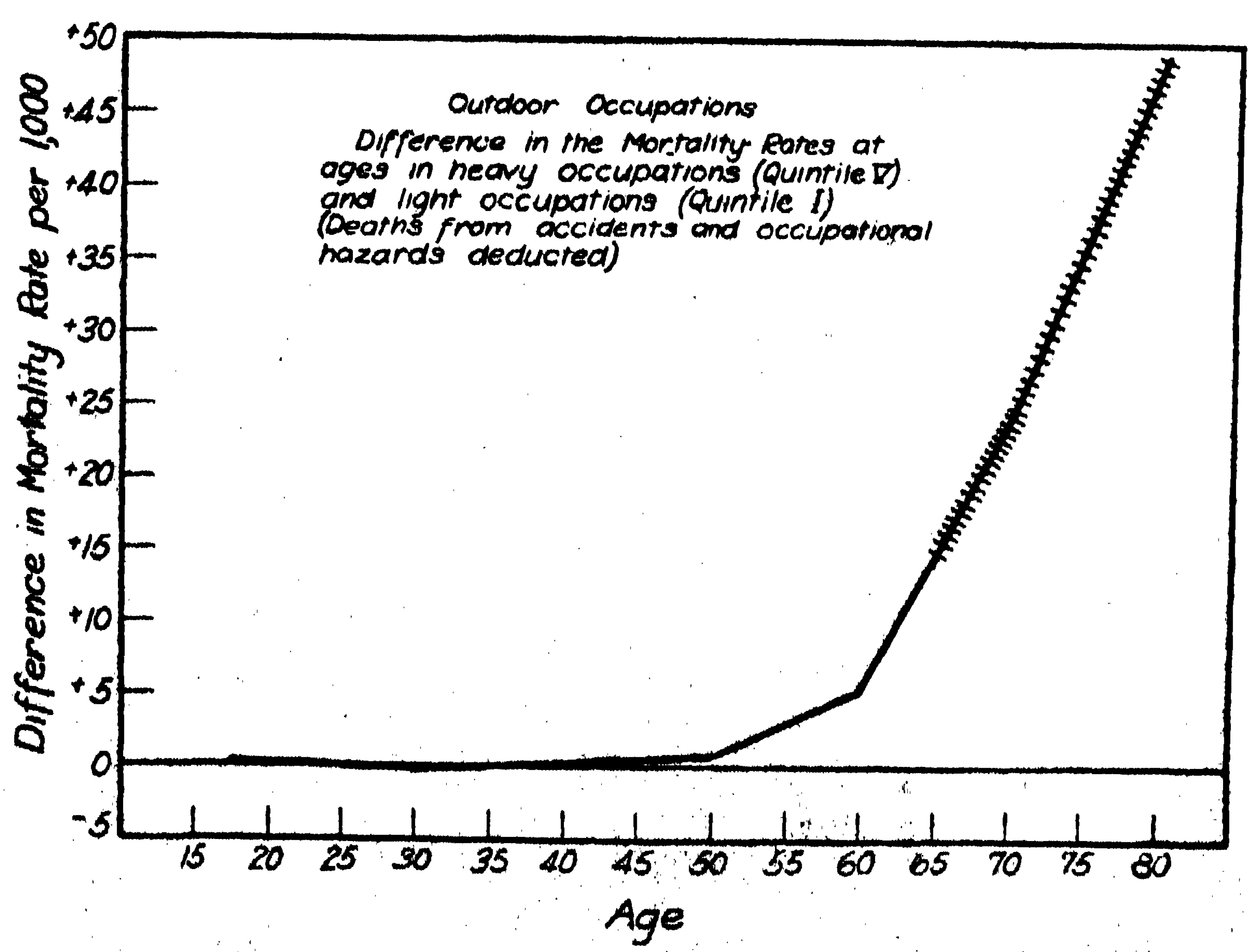


FIG. 15. SAME AS FIG. 14, EXCEPT THAT IT DEALS WITH OUTDOOR OCCUPATIONS.

tality whether the occupation involves light or heavy physical labor. After roughly age 40 to 45 it appears that a man shortens his life, by definite amounts, in proportion as he performs physically heavy labor.

VII

As the termination of this discourse is now near at hand, it is evident that nothing at all has been said about many aspects of the problem of human longevity. These omissions are not to be regarded as consequences of any lack of interest or intrinsic importance in some of the omitted topics. It is mainly a consequence of that profoundly significant fact that an hour includes only sixty minutes.

But certain omissions have been deliberate and from principle. Much might have been said regarding various theories and speculations about the duration of life that have been put forward in increasing number in recent years. Mostly these have come, directly or indirectly, from consideration of the results of experimental work with lower forms of life. Much of this work has been of fine quality and great intrinsic interest and importance to biology as a science. Some of these experiments have led to highly spectacular success in absolute or relative prolongation of life. For example it has been possible to manipulate seedlings in such a manner as to make them live more than *seven times* as long as they normally would on a given supply of energy and matter as resources for living.[11] Partial or intermittent starvation of various lower animals has led to similar results in the hands of various workers. There is, however, at the present time no smallest reason or justification for even suggesting that results of this sort, and various other sorts in comparable status, have any application whatsoever to human longevity. To insinuate, as some have done in calculated newspaper publicity, that results of this sort might lead in the near future to a startling extension of the human life span is only a bit of naive professorial *Reclam*. When just one single life has been provably prolonged by the application of any such principle its discoverer will not need to advertise. The medical profession will know all about it, and will be testing its possibilities for further extension.

Again it will have been noted that no advice has been given this evening about how to conduct life so to live long. The reason for this omission is simple. I am not a medical man. It is the proper professional business of medical men to instruct and advise people about healthy and continued living. They have done well at it, and their collective wisdom about it waxes day by day. On the other hand, detached observation suggests that when laymen take on the job, as all too many of them love to do, the results have not been quite universally all that could be desired. Some conspicuous examples could be cited by way of illustration of this point, without having to wander very far geographically. The truth is, as every physician knows, that human life and living are extremely complicated matters, not amenable to simplification by formula or to amelioration by panacea. Really helpful advice about unravelling these complications will come only from the wisdom that grows out of experience and knowledge. The purity of heart and nobility of purpose of bustling "do-gooders" or the ready omniscience of gentry eminent in branches of science *other* than medicine are poor surrogates for the real knowledge and wisdom of the seasoned medical practitioner in the search for longevity.

The literature of longevity is full of advice, recipes and precepts for the attainment of long life. These precepts touch upon nearly every conceivable as-

[11] S. A. Gould, R. Pearl, T. I. Edwards and J. R. Miner, *Annals of Botany*, 48: 575–599, 1934.

pect of personal physiology and hygiene. Yet it is an odd fact that careful study of our collection of life records of nonagenarians and centenarians leads, as one of the broadest generalizations it is possible to make from them, to the conclusion that these 2,000 and more persons exhibited substantially the same range and degree of variation relative to these various items of personal hygiene as is found amongst people in general. Some were light eaters, others on the gluttonous side; some used tobacco, others didn't; some drank heavily, others were teetotalers; some slept a lot, others didn't; some had been in robust health all their lives; others had been ailing a great part of the time; and so on. In only one outstanding respect besides great longevity did the group markedly differ from the generality of mankind, on the whole. That is the fact that a vast majority of these extremely longevous folk were of a placid temperament, not given to worry. They had taken life at an even, unhurried pace. In this respect this human material agrees with and confirms a generalization that has emerged from experimental studies on life duration. It is that *the length of life is generally in inverse proportion to the rate of living.* The more rapid the pace of living is, the shorter the time that life endures. This relationship has been shown to exist for a variety of forms, including plants, various lower animals, insects and men.[12] It is a relation that is obviously in some degree within the power of individual, personal control.

The search for longevity is not ended, though this discourse is. In the view of the biologist the search has only just got well under way. A great deal more will be learned, and just possibly we may find out how to lengthen significantly and at will the span of human life, instead of merely increasing its average duration. But if and when this happens the biologist and medical man will probably need to call for the help of the sociologist, the economist and the philosopher to fix over the world, so that it will be better suited for old people to live in than it now is.

[12] For a general discussion of this topic see R. Pearl, "The Rate of Living." New York: Alfred Knopf, 1928. Pp. 185.

BENJAMIN FRANKLIN

THE FINAL MODEL OF THE HEROIC STATUE NOW BEING SCULPTURED BY JAMES EARLE FRASER, WHICH IS TO BE UNVEILED IN FRANKLIN HALL OF THE FRANKLIN INSTITUTE, BENJAMIN FRANKLIN PARKWAY, PHILADELPHIA. THE STATUE WILL BE OF WHITE "SERAVEZZA" MARBLE, APPROXIMATELY TWICE LIFE-SIZE. WHEN ERECTED UPON ITS PEDESTAL IN FRANKLIN HALL, IT WILL RISE TO A HEIGHT OF 18 FEET ABOVE THE FLOOR.

THE PROGRESS OF SCIENCE

THE MEMORIAL TO BENJAMIN FRANKLIN

As it was so often during his life, the name of Benjamin Franklin will be "on the tip of the tongue" in scientific and educational circles during the latter part of May of this year when a new national shrine will de dedicated to the memory of the great natural philosopher and American patriarch in Philadelphia, the city where Franklin sought a successful career as a printer, and found not only that but also subsequent world-renown in the fields of science and statesmanship.

President Roosevelt has expressed his intention of unveiling on May 19 a heroic white marble statue of Franklin in a stately memorial room in the Franklin Institute, on Philadelphia's Benjamin Franklin Parkway. The statue is the work of the noted American sculptor, James Earle Fraser.

The memorial room, known as Franklin Hall, will be the spiritual center of the classic structure which houses the Wonderland of Science museum and the Fels Planetarium of the Franklin Institute. Constructed entirely of marble of different varieties, the hall will be bare of any adornment other than the heroic statue and its own architectural charms. It is octagonal in shape and 82 feet in length, width and height.

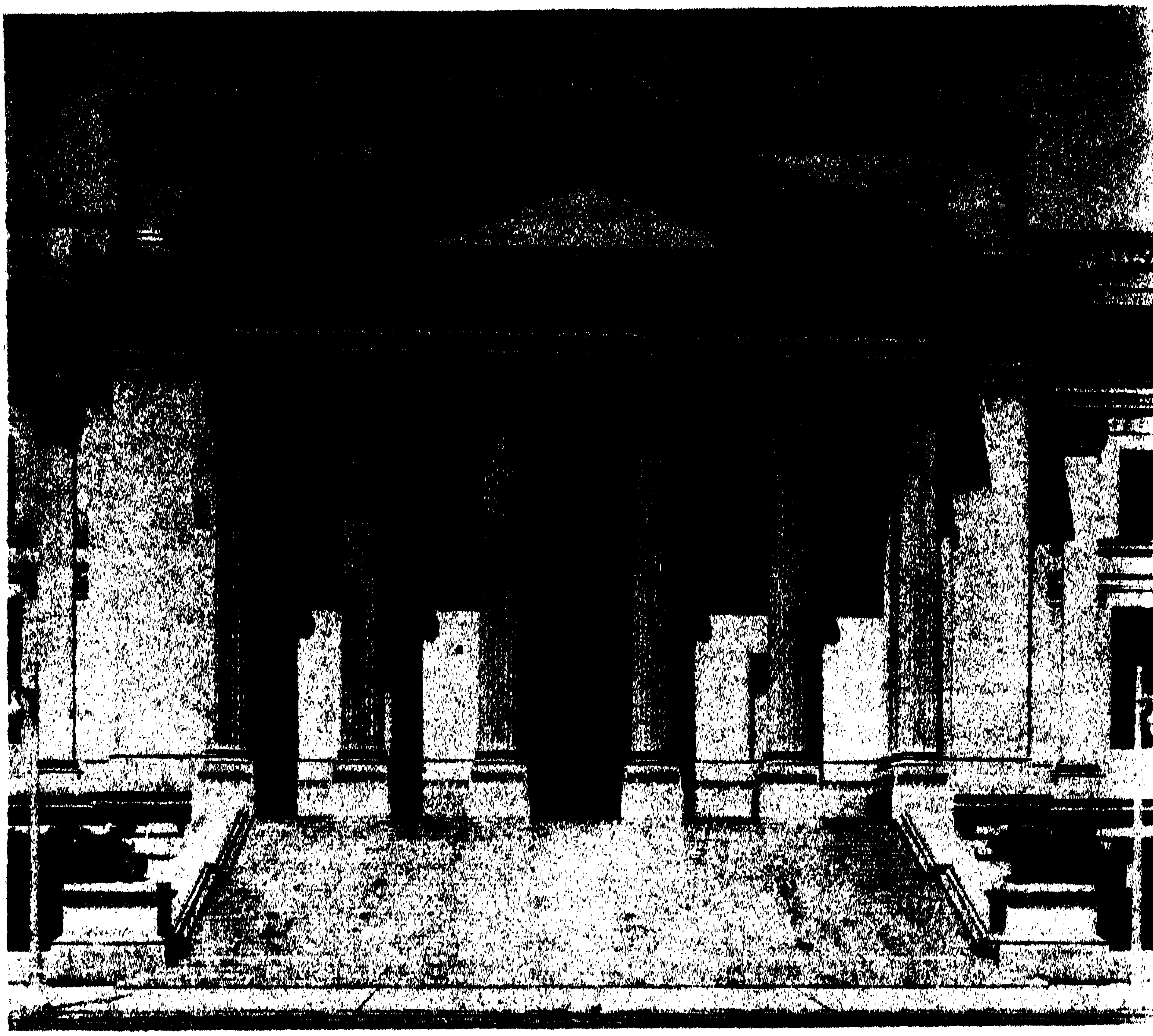
When erected upon its massive pedestal of Rose Aurora marble from Portugal, the statue will rise to a height of 18 feet above the floor. It will be a seated figure of Franklin, approximately twice life size. The combined weight of pedestal and statue will be 120 tons.

Franklin Hall will be the scene of memorable events during the dedication. Following the unveiling ceremony, diplomatic representatives of France and Britain and the Canadian Minister will honor the statue by placing wreaths at its foot. In the evening of May 20, the University of Pennsylvania, founded by Benjamin Franklin, will confer degrees there, and the Franklin Institute will award medals.

"Many-sided" is a term often applied to Franklin; which is not remarkable when it is recalled that he was noted as a printer, author, public-spirited and philanthropic citizen, natural philosopher, inventor, statesman and diplomat; and further, that as a natural philosopher, his interests and achievements were not confined to one branch of science, but practically ran the gamut of the fields of scientific learning of his day, including aeronautics, agriculture, astronomy, botany, chemistry, electricity, geology, hydrostatics, hygiene, mathematics, medicine, meteorology, navigation, oceanography, optics, orthography, paleontology and physics. This was borne in mind in planning the program for the three days of dedicatory exercises by a large organization of prominent Philadelphians, headed by Mr. Philip C. Staples, president of the Franklin Institute; the Honorable George Wharton Pepper, honorary chairman; and Dr. Henry Butler Allen, secretary and director of the Franklin Institute, general chairman.

The first day, May 19, will honor "Franklin, Patriot and Man"; the second day, May 20, "Franklin, Philosopher and Educator"; and the third day, May 21, "Franklin, Printer and Business Man." Furthermore, the second day will be featured by a notable educational and scientific gathering, at which different branches of pure science will be discussed.

This meeting, which will be held in the lecture hall, where each season the Franklin Institute presents for its members the scientific lectures for which it has been noted since its inception 114 years ago, will be addressed by eminent scientists and educators of two conti-



THE FRANKLIN INSTITUTE

PORTALS OF THE FRANKLIN INSTITUTE BEARING THE INSCRIPTION "IN HONOR OF BENJAMIN FRANKLIN." THIS ENTRANCE LEADS DIRECTLY TO THE FRANKLIN MEMORIAL AND ITS HEROIC STATUE OF FRANKLIN.

nents. That it will be a meeting such as Franklin himself would revel in, were he alive, is evident from the list of those who have accepted invitations to present papers on various pure sciences.

It will be gratifying to admirers of Benjamin Franklin that the head of a world-renowned Parisian medical society of the present day—Dr. Louis Martin, director of the Pasteur Institute—will come to the United States to be one of the speakers in the pure science meeting. Although not a medical doctor, Franklin became a man of note in the medical world and was elected a member of the Royal Medical Society of Paris and the Medical Society of London. His fame in this respect was nowhere greater than in Paris, where he represented the American colonies with such signal success during the Revolutionary War. The King of France appointed him a member of a commission to investigate the claims of Anton Friedrich Mesmer as to "animal magnetism," and it was Franklin who drew up the report exposing Mesmer.

Another who will come from abroad to pay tribute to Franklin will be Sir James Colquhoun Irvine, principal and vice chancellor of Saint Andrews University, Aberdeen, Scotland. It was at

Saint Andrews that the first of his numerous honorary degrees was conferred upon Benjamin Franklin. Others who will present papers are Dr. George D. Birkhoff, mathematician of Harvard University; Arthur L. Day, director of the Geophysical Laboratory at the Carnegie Institution, Washington, D. C.; Dr. Merritt L. Fernald, botanist, Harvard University; Dr. Gilbert N. Lewis, dean of the college of chemistry, University of California; Dr. C. E. K. Mees, director, research laboratory, Eastman Kodak Company, Rochester, N. Y.; and Dr. Thomas H. Morgan, zoologist, of the California Institute of Technology. Presiding will be Dr. E. G. Conklin, executive vice president of the American Philosophical Society, which was founded by Benjamin Franklin and of which he was president for many years.

Representatives of engineering and professional societies will attend another meeting to be held in the lecture hall on May 21, which will be devoted to applied science. Dr. Harvey N. Davis, president of the Stevens Institute of Technology, Hoboken, N. J.; Dr. Willis R. Whitney, vice-president in charge of research of the General Electric Company, Schenectady, N. Y.; Dr. W. E. Wickenden, president of the Case School of Applied Science, Cleveland, Ohio; and Mr. Abel Wolman, chief engineer, State Department of Health, Baltimore, Md., will be the speakers. Mr. Leonard T. Beale, president of the Pennsylvania Sale Manufacturing Company, will preside. In the evening a banquet will be held at which the Honorable Herbert C. Hoover will give the principal address.

The Franklin Institute is securing many special exhibitions which will be added to the 4,000 action displays in its Wonderland of Science museum during the dedication and the weeks to follow. This distinctive museum has sections devoted to astronomy, aviation, the graphic arts, chemistry, medicine, marine transportation, music, electrical communications, illuminating engineering, railroad engineering, physics, fire fighting and prevention, materials of construction, prime movers and mechanisms; also a seismograph and a large observatory. Last year the Wonderland of Science and the Fels Planetarium attracted more than half a million visitors. This year, because of the interest that will center upon the dedication, it is expected that these numbers will be greatly increased.

The new Benjamin Franklin Memorial, perpetuating through the arts the memory of Franklin, the man, in this stronghold of science and mechanics, to which Franklin, the natural philosopher, contributed so notably, will honor one of the greatest of Americans with one of the world's outstanding mementos of a life of distinguished achievement.—C. L. J.

THE FIFTIETH ANNIVERSARY OF THE AMERICAN PHYSIOLOGICAL SOCIETY

The three great events in the history of American physiology have been the development of the experimental laboratory, the establishment of the *American Journal of Physiology* and the organization of the American Physiological Society. This year the society celebrated the fiftieth anniversary of its founding.

The celebration took the form of a special program at the recent annual federation banquet and the preparation of a history of the society.

At the banquet four of the five living original members were present as guests of honor: Professor R. H. Chittenden, emeritus professor of physiological chemistry at Yale, Professor William H. Howell, emeritus professor of physiology at Johns Hopkins, Professor Joseph Jastrow, former professor of psychology

MEMENTO PRESENTED TO MEMBERS OF THE AMERICAN PHYSIOLOGICAL SOCIETY ON THE OCCASION OF ITS FIFTIETH ANNIVERSARY CELEBRATION

at Wisconsin and Professor W. P. Lombard, emeritus professor of physiology at Michigan. Dr. F. W. Ellis, Monson, Massachusetts, the fifth, was unable to be present. For the occasion Dr. W. T. Porter, the founder and first editor of the society's journal, was made honorary president of the society and acted as toastmaster. Dr. J. J. Abel, emeritus professor of pharmacology at Johns Hopkins University, was a distinguished guest. Dr. W. H. Newton brought the greetings from the British Physiological Society, and Dr. C. H. Best represented the Canadian Physiological Society.

The program itself consisted of the roll call of the organization members by President Walter E. Garrey, the introduction of the original members present and eulogies of the three founders; H. P. Bowditch, by Walter B. Cannon; H. Newell Martin, by Dr. W. H. Howell, and Dr. S. Weir Mitchell, by Dr. A. J. Carlson.

The American Physiological Society was actually founded on Friday, December 30, 1887, the organization meeting being held in the physiological laboratory of the College of Physicians and Surgeons, 437 West 59th Street, in New York City. The call for the meeting was a small mimeographed slip signed by S. Weir Mitchell, H. N. Martin and H. P. Bowditch. It is probable that the idea of forming a society originated with Dr. Mitchell, but certainly Dr. Martin, who was an original member of the British Physiological Society, was also responsible, particularly for the constitution and early policies. Seventeen were present at the organization meeting and eleven more were made members, a total of twenty-eight. The membership included practically all the biological scientists of the day who were using the experimental physiological method. Besides the founders themselves the list included such celebrities as John C. Dalton, then president of the College of Physicians and Surgeons, J. G. Curtis, S. Stanley Hall, Wm. Osler, V. C. Vaughan and Wm. H. Welch.

A "History of the Physiological Society from 1887 to 1937" was one of the undertakings sponsored by the semicentennial committee. The first twenty-five years of this story has been written by Dr. William H. Howell, an original member, an early president and one closely associated with the society throughout its career. To Dr. Charles W. Green, long an efficient secretary and recently president, has fallen the lot to write of the period of growth which has taken place during the last twenty-five years.

In the growth of an organization comparisons are of interest. At the first annual meeting of the American Physiological Society thirteen members were present and five papers were presented. At the fiftieth annual meeting the members present were in the hundreds and the total number of papers and demonstrations was 422. For the first twenty-five years one session each half day was enough to take care of all those wishing to make reports. At the fiftieth annual session five sections were continuously in action. As a matter of fact these statements cover only a small part of the society's growth, for from its membership three separate societies have now been segmented. In 1906 the American Society of Biological Chemists was formed; the Society for Pharmacology and Experimental Therapeutics appeared in 1908 and the Pathological Society in 1913. These separations after all were for matters of convenience and made no difference in the intimacy of the group, for they were at once organized into one general organization, the Federation of Societies for Experimental Biology and Medicine. The first meeting then of the Physiological Society with its attendance of thirteen and five papers should really be compared with the 1938

federation meeting with its attendance of over 2,200 and 745 papers.

In the period of fifty years certain trends may be noted. The tendency toward greater specialization has always been apparent. Sections devoted to circulation, respiration, electrophysiology and endocrines are practically separate society meetings. The type of research has often closely followed the development of special methods. The use of the x-ray, sensitive galvanometer and the amplification tube has greatly increased research possibilities. Demonstrations, at first the public performance of some new experiment, have now been crowded out for want of space, and this year "static demonstrations" were employed. Free discussion, a characteristic of the early days, has been somewhat revived by the multiplicity of sections. At first the meeting place was invariably the laboratory of some medical school, but now the largest hotel, auditorium or armory is necessary to accommodate the membership. Throughout the years two characteristics have, however, remained unchanged, and on these the success of the organization has always rested. Membership has always depended on a continuance of activity in physiological research, and there has always been the warmest of welcomes extended to scientific youth.

The American Physiological Society from its foundation has been an important factor in the scientific life of our country. It is a forum in which are presented the current researches in the physiological sciences. It is the owner and manager of two great journals. It is the mother of societies. Not only has its past been honorable and productive, but at the present moment it is more prosperous in point of members and scientific activity than at any period of its history.

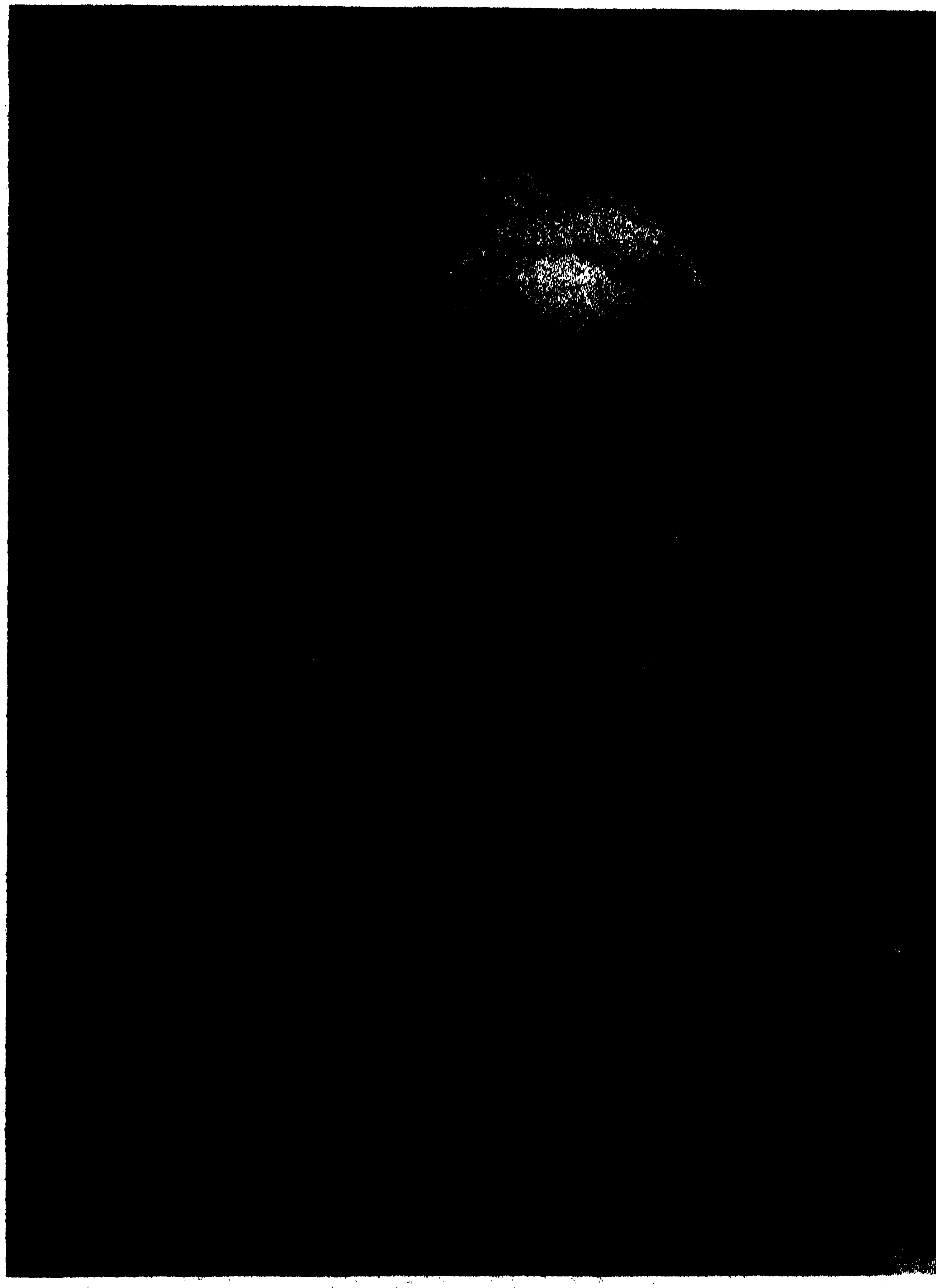
WALTER J. MEEK,
Chairman of the Semi-centennial Meeting
UNIVERSITY OF WISCONSIN

JOHN MUIR AND THE NATIONAL MONUMENT IN HIS HONOR

THE one-hundredth anniversary of the birth of John Muir, conservationist and explorer, occurred on April 21, 1938. He was born of Scottish parents in Dunbar, Scotland, where he lived the first ten years of his life. When Muir was eleven years of age his father emigrated to America, taking up a homestead in Wisconsin, then a frontier wilderness. In his early twenties Muir attended the University of Wisconsin, but, characteristic of his independence of thought, he did not follow a formal course of study but chose his own courses, which were mainly chemistry, geology and, later, botany. This independence was evidenced again, in later years, when he refused the chairs offered him by Harvard University and the Massachusetts Institute of Technology. He felt that such academic preeminence would not compensate for the loss of his freedom to roam the wilds.

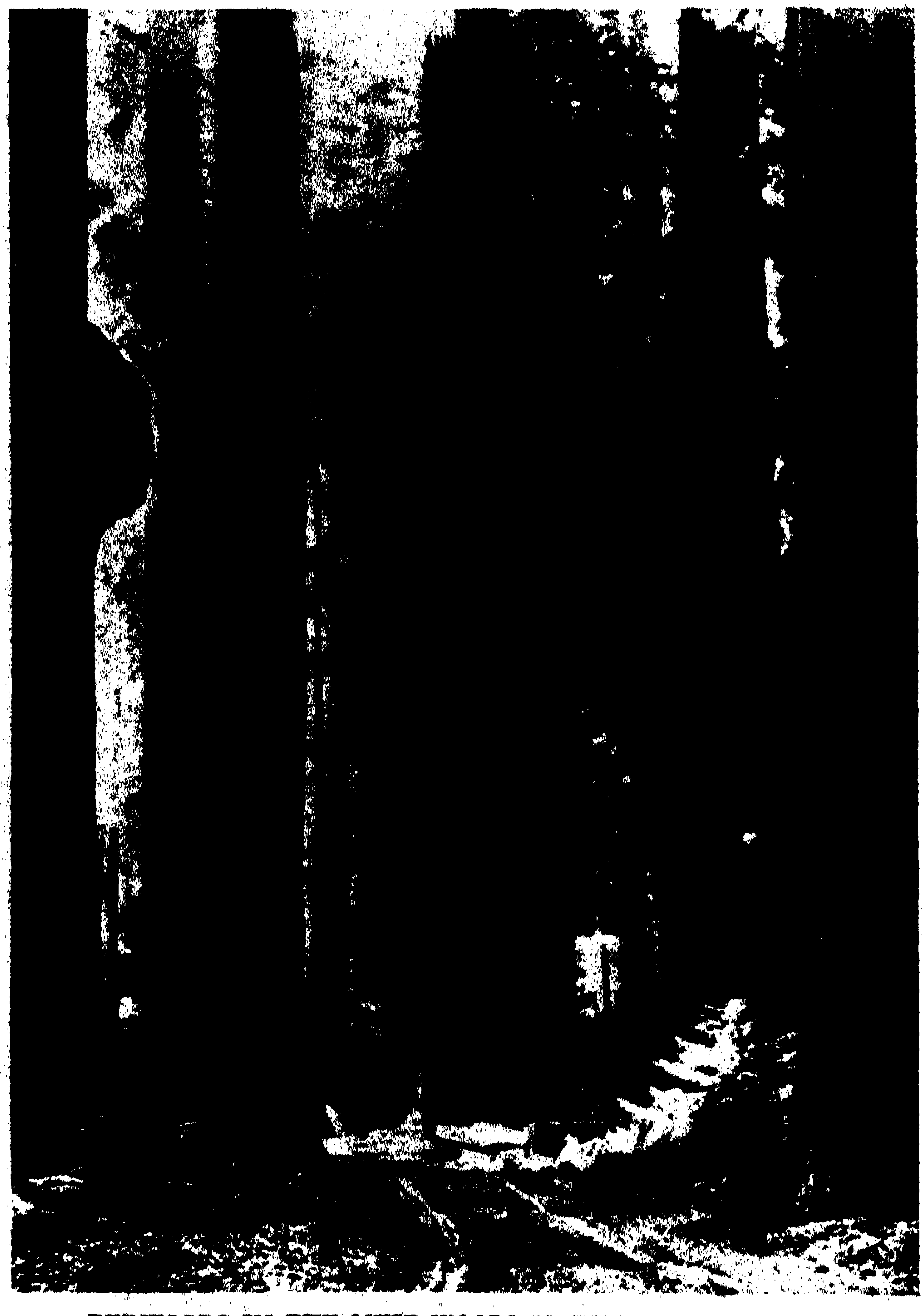
John Muir, though at first interested in applying himself to a mechanical trade, was a wanderer nearly all his life. He was injured while working in an Indianapolis factory and as a result of the accident lost the sight of one eye. Soon after his recovery he set out on a thousand-mile trip to the Gulf of Mexico. Long afterward his notes were published as "A Thousand Mile Walk to the Gulf." These notes are valuable because of the picture they present of the attitude of that period on the subject of conservation.

From Florida he went to Cuba, took passage to New York and from New York sailed, steerage, around Cape Horn to California. For a decade he made his principal abode the valley of the Yosemite, and from there made many expeditions into the High Sierra. He explored mountain and glacier and studied their



JOHN MUIR

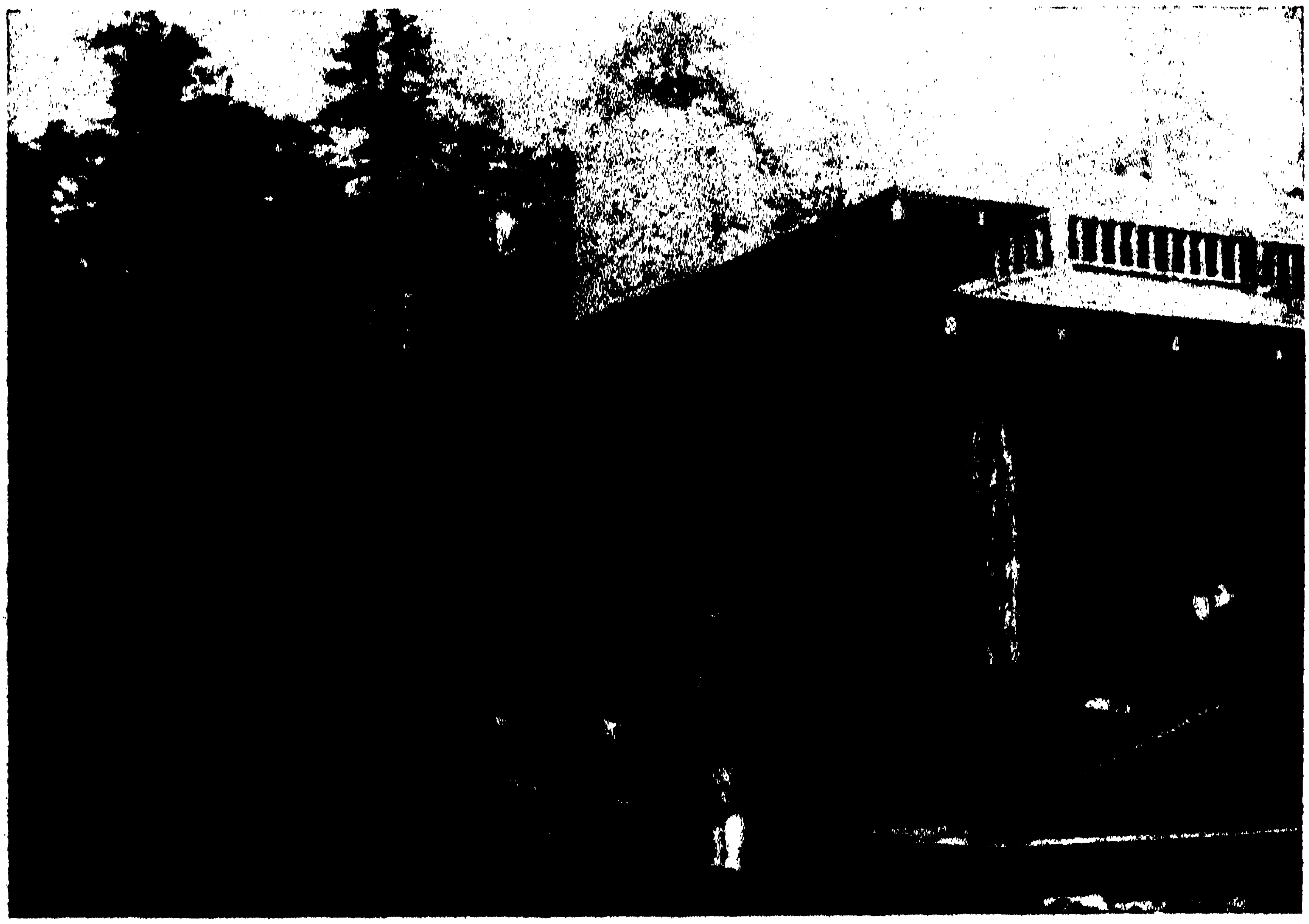
PHOTOGRAPHED FROM THE PAINTING BY HERBERT A. COLLINS, A STAFF ARTIST OF THE WESTERN MUSEUM LABORATORIES OF THE NATIONAL PARK SERVICE OF THE DEPARTMENT OF THE INTERIOR. THIS PICTURE IS ON EXHIBITION IN THE MUSEUM AT THE MUIR WOODS NATIONAL MONUMENT.



REDWOODS IN THE MUIR WOODS NATIONAL MONUMENT

geologic past. His first published works were the series, "Sierra Studies." Today he is remembered in the name of "The John Muir Trail," which extends from Yosemite to Mount Whitney. But Muir's travels were not confined to the West and South. His first trip to Alaska was made in 1879. At that time he discovered Glacier Bay and the great glacier which bears his name. Muir also explored the upper reaches of the Yukon and McKenzie rivers and in 1890 journeyed through the Caucasus, Siberia, Manchuria, Japan, India, Egypt, Austria and New Zealand.

When he was forty-two Muir married the daughter of one of the most successful horticulturists in California. He rented part of his father-in-law's holdings and became a successful fruit raiser and was able to retire within a ten-year period. Muir frequently left the Alhambra Valley on trips of exploration and in 1889 conducted Robert Underwood Johnson, one of the editors of the *Century Magazine,* into the Yosemite. This trip had far-reaching effects, for it led to the Muir-Johnson conservation movement, for which both labored for the rest of their lives. Legislation was passed in 1890 which established Yosemite National Park, Sequoia and General Grant National Parks.



OLD MUIR WOODS INN

SHOWING, LEFT TO RIGHT, JOHN MUIR, WILLIAM KENT (DONOR OF MUIR WOODS NATIONAL MONUMENT) AND GIFFORD PINCHOT. PICTURE TAKEN ABOUT 1913. THE INN HAS SINCE BEEN DESTROYED BY FIRE.

William Kent presented to the nation the grove of redwoods near San Francisco with the understanding that the tract should bear the name of the man who saved so many trees from destruction. The Muir Woods National Monument was created by presidential proclamation on January 9, 1908. It contains 427 acres and is situated at the foot of

Mount Tamalpais, in southern Marin County, not far from the city of San Francisco.

Many trees in the Muir Woods grove are centuries old, yet the Redwood does not reach the extreme age commonly accredited it. Often the Big Tree of the Sierra and the Redwood of the coast are confused. Both are Sequoias, but separate and distinct species, the Redwood being scientifically named *Sequoia sempervirens* and the Big Tree, *Sequoia gigantea.* The Redwood is found only along the coast and is the species which grows the tallest of any tree in the world, now reaching the extreme height of 364 feet. It seldom exceeds a diameter of 20 feet or an age of 2,000 years. The Big Tree grows only on the western slope of the southern Sierra Nevadas and attains an age of 4,000 years or more and a diameter of over 35 feet. Long ago fire ran through the grove at Muir Woods and left in its wake charred stumps and deep fire scars in the butts of living trees. Circles of mature trees surround fire-killed stumps whose roots sent up and fed these now mature trees shortly after fire had killed the parent tree. The fire scars, weathered by time, add to the picturesqueness of the scene.

In addition to its natural beauty, the woods is noted for abnormal growths, such as burls, albino shoots and fasciated formations on Redwoods, while interesting natural grafts and peculiarities are found on other trees. Burls range in size from those sold in florists' shops to huge ones six or more feet in diameter. Large root burls appear to be bowlders embracing the foot of the tree, while smaller burls occur in a variety of sizes and shapes upon the trunks. Various other trees are abundant throughout the woods and contribute their part to the Redwood forest type. California laurel, tan bark oak and Douglas fir are plentiful, while madrone alder, nutmeg and buckeye are found scattered through the grove. In Fern Canyon a Douglas fir 8 feet in diameter has been dedicated to the memory of the late William Kent.

Multitudes of flowers and ferns are found growing throughout the woods, and during the spring and early summer their blossoms add to the grace, charm and solemnity of the Redwoods. Wildlife abounds within the monument. Deer wander up and down the forest aisles at dawn and dusk. Raccoons are plentiful and bobcat, fox, coyote, skunk and mountain lion are occasionally seen. Birds are also numerous, but the majority of them spend their time in the tall tree tops and are not apparent to the average visitor. Fry and fingerlings of salmon and steelhead trout swarm in countless numbers in the larger pools, and when winter rains have raised the water level in Redwood Creek, visitors may see, but not catch, huge salmon and steelhead fighting their tortuous way up the rapids to the spawning beds within the monument.

CORRESPONDENT

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UTILITARIAN ASPECTS OF GEOPHYSICS

By A. G. McNISH

DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

THE last few years have witnessed the rapid growth and integration of a distinct branch of science dedicated to investigating the physical properties and processes of the earth. In addition to its purely intellectual fascination this new geophysical science is proving of intense practical importance to our present-day civilization. The geophysicist may point with pride to past and present services of his science and, if permitted a little speculation, may forecast even greater services in the future.

The ways in which geophysics may be of service can be classified in three categories: First, direction toward a more economical exploitation of natural resources; second, prediction of natural phenomena and recommendation as to the most effective means of avoiding or taking advantage of their effects; and third, actual methods of avoiding unfavorable occurrences and causing favorable ones, which, speculative as it may seem, are not outside the bounds of possibility. That man may some day be master of the earth and not merely an animal living upon it depends upon the extent to which we avail ourselves of the scientific knowledge which we have and can acquire. A brief discussion of the value of geophysics may be presented more clearly by considering each department of the science separately.

METEOROLOGY

No one who has experienced the vicissitudes of weather can fail to recognize the importance of meteorological forecasts. That the "weather man" has sometimes erred in no way argues against the utilitarian character of his predictions. During past years his prognostications have been based upon meager information derived largely from the thin layer of air in which we move, close to the earth's surface. Thus, the meteorologist has had to content himself with a two-dimensional picture to solve what is actually a three-dimensional problem.

But to-day flights by airplane at a few scattered stations supply data taken along the third dimension at various heights in the atmosphere. Fragmentary as they are, these bits of information reveal a more comprehensive picture of the processes which have and are about to occur, of the nature of various air-masses, their origin and motion. The present trend in the science is toward the acquisition of more complete and detailed information concerning the higher layers of the atmosphere upon which so much of our weather depends. When these facts have been acquired and correlated a more satisfactory method of forecasting will follow with attendant benefits to society. This new information will be brought to us by radio-meteorographs

Photo by courtesy United States Weather Bureau.

RADIOMETEOROGRAPH ATTACHED TO PARACHUTE AND SOUNDING BALLOON

MECHANICAL WEATHER-OBSERVERS ARE SENT TO GREAT HEIGHTS IN THE ATMOSPHERE IN FAIR WEATHER OR STORM WHENCE THEY REPORT BY RADIO THE CONDITION OF THE AIR AT VARIOUS HEIGHTS. THIS NEW, IMPROVED MEANS FOR OBTAINING REGULAR METEOROLOGICAL DATA IS OF GREAT ASSISTANCE TO THE FORECASTER.

carried to great heights by small balloons. Expensive flights by airplane, which are not possible in bad weather when they are needed most, will no longer be necessary. Instead robot weather-observers will be carried aloft and send back radio signals describing atmospheric conditions at various heights.

The possibility of forecasting weather for entire seasons has received much attention from meteorologists. Vast amounts of data are being accumulated to ascertain if such forecasts are possible and to guide in making them if they are. The St. Swithin's Day myth and other superstitions regarding weather were blasted long ago by scientific investigations. Instead, some investigators are looking to variations in solar radiation and sunspots for indications of weather, but without success. Ocean-currents, ice-fields and snow-cover, and associations of

weather in one part of the world with subsequent weather in another part have all been studied with the view of long-range forecasting. The value of reliable seasonable forecasts to farmers, merchants and industrialists is self-evident. Meanwhile, the search goes on.

Beyond the immediate scope of forecasting weather is the study of climate, which is only the weather on a large scale. Other branches of geophysics show that great climatic changes have occurred in past ages. Since change itself is the only constant thing on this earth, our climates must be changing even now, perhaps too slowly to be noticed, perhaps not. The terrific dust-storms to which this country has been subjected during recent years may be but temporary; on the other hand, they may be forerunners of a complete change in climate which may transform the central part of our country into a vast desert. A more far-sighted national policy in the past and more thoughtful exploitation of the soil in the light of present climatological knowledge would have mitigated the severity of these plagues of dust. It is of utmost importance to ascertain the real geophysical facts involved.

Hydrology

It was no provision of nature which placed a river near almost every large city. The importance of water-systems to civilization has been recognized by every historian. Not only do waterways provide ready means of cheap transportation, but they likewise perform the twofold service of bringing water to our cities and of carrying away filth which otherwise would infect the inhabitants. Artificial irrigation has been man's method of combating an arid climate—one of his supreme conquests of nature. Modern civilization goes even further and harnesses the power of rivers and transforms it into electric power. Since most of the water which runs in rivers seeps through the soil, the study of ground-water is important. Although man has not as yet learned to control the rain which falls upon the earth, he has learned how to make the most economical use of that which does fall. He has learned that forests are necessary to prevent the rain from rushing too madly to the sea and he has learned that certain types of plants permit the rain to penetrate deeper into the soil than others. Application of some of this knowledge might have done much toward diminishing ravages of the drought which has recently laid waste to large areas of our land.

While rivers perform great services to man, sometimes their devastations outweigh their services. Periodic floods have won for the Yellow River the opprobrious epithet "China's sorrow." Floods, however, are not beyond control. While we can not control the amount of water which falls into a river-basin, the science of hydrology teaches us the most effective ways of keeping a river within its banks, and failing this at least makes predictions as to the imminence and magnitude of flood-dangers. In a few notable cases, by means of dams and reservoirs, the amount of water flowing through a river has been brought under almost complete control.

Of greater importance than the threat against man's creations during floods is the vaster danger which threatens the economy of entire regions, namely, abnormal soil-erosion. Under natural conditions, erosion is usually a gradual process, but with cultivation of the land the quantities of material carried away by floods are principally topsoil, the very basis of successful agriculture, which nature has required centuries to produce and which man may never adequately restore by artificial means. The prevention of these ravages which have already laid waste to large areas of our land is one of the many services the science of hydrology is capable of performing.

Photo by courtesy United States Bureau of Reclamation.

BOULDER DAM AND LAKE MEAD

STEMMING THE MIGHTY COLORADO RIVER WHERE IT THREADS BLACK CANYON, BOULDER DAM RISES 726 FEET ABOVE BED-ROCK AND CREATES LAKE MEAD, 40 MILES WIDE AND 115 MILES LONG, THE LARGEST ARTIFICIAL LAKE IN THE WORLD. AGRICULTURAL LANDS IN RICH IMPERIAL VALLEY WILL BE PROTECTED FROM FLOODS AND FURNISHED A REGULAR SUPPLY OF WATER FOR IRRIGATION. ELECTRICITY IS GENERATED FOR THE THICKLY POPULATED AREAS OF SOUTHERN CALIFORNIA AND OTHER NEARBY REGIONS.

Oceanography

Though man is primarily confined to the land surface of the earth, he can not be unmindful of the fact that three-fourths of the globe upon which he lives is covered by water. Though much of oceanography belongs to other branches of science, the physics of the ocean constitutes no small part of the subject. Oceans form the highways between nations; a proper knowledge of their tides and currents, of the topography of the oceanic floor, of marine meteorology and of the compass-directions at sea are essential to our maritime activities. The winds and currents of the oceans are important in affecting the drift of icebergs from the frozen polar seas to warmer regions. One needs only to think of the disaster which the name *Titanic* recalls to realize the importance of knowledge concerning the drift of icebergs on the open seas.

In addition to their service as highways of nations, the oceans perform valuable services to society in many other ways. Vast herds of living creatures graze in the natural meadows of the sea untended by cowboys or shepherds and supply the world with much of its supply of food. It is estimated that the output of ocean fisheries is nearly $1,000,000,000 annually. Preservation of these fisheries during the growth of a mechanized civilization is one of the problems faced by oceanographers. Since proximity to centers of civilization make a fishing-ground more valuable, it is essential that such grounds are not injured by pollution from cities and their industrial plants. Knowledge of tides and currents assists in efficient exploitation of the natural resources of the sea.

Photo by courtesy United States Geological Survey.

FLOWING WELL IN ROSWELL ARTESIAN BASIN, NEW MEXICO

STUDY OF SUBTERRANEAN WATER-SUPPLIES ENABLED HYDROLOGISTS TO BRING THROUGH THIS GUSHING WELL DELIVERING 3,190 GALLONS OF WATER A MINUTE IN A LAND OF CREOSOTE BUSH AND MESQUITE GRASS. EFFICIENT, ECONOMICAL USE OF THESE NATURAL RESOURCES IS FOSTERED BY THE SCIENCE OF HYDROLOGY.

Like most natural benefactors, the ocean is frequently a great destroyer. Storms which do mild damage to inland cities visit greater fury upon those situated upon the sea-coast. Tremendous tides heaped up by gales and hurricanes and rendered more devastating by large waves which top them cause great damage to life and property. The predic-

Photo by courtesy United States Coast Guard.

COAST GUARD CUTTER ON NORTH ATLANTIC ICE–PATROL

PATROLLING THE SHIPPING LANES OF THE NORTH ATLANTIC ON INTERNATIONAL SERVICE OF ICE OBSERVATION, COAST GUARD CUTTERS CHART THE POSITIONS OF MENACING ICEBERGS FROM MARCH TO JULY. OBSERVATIONS OF WIND, CURRENTS AND CONDITION OF THE SEA-WATER AFFECTING DRIFT OF ICEBERGS ENABLE OCEANOGRAPHERS TO PREDICT THEIR FUTURE TRAVELS.

tion of such tides as well as the ponderous waves such as broke upon distant shores after the eruption of Krakatoa constitute one of the oceanographer's tasks.

Geodesy

The science of measuring the earth is older than the pyramids. Its importance is indisputable. Essentially it is the function of geodesy to determine within proper limits of accuracy the size and shape of the earth and to correlate points on its surface to best meet the requirements for mapping, engineering and science. The modern geodetic survey does more than determine latitudes, longitudes, elevations, lay out boundaries and locate points on which rights of property are based. Geodetic control and the maps based on it are of inestimable value to the engineer who would build roads, canals, bridges, dams and the countless features of man's exploitation of the earth's surface.

At first consideration the determination of the size and shape of the earth appears to be an academic problem, but it is of intense practical importance because the earth is far from spherical in form. Accurate mapping must take this lack of sphericity into account. In astronomical observations the figure of the earth must be allowed for because a plumb-line does not point directly toward the center of the earth at all places on its surface. Variations in gravitational force from place to place arise partly because of the departure of the earth from truly sperical form. This is strikingly revealed by variations in the rate of a clock controlled by a gravity-pendulum if it is carried to different parts of the earth.

Beyond this the geodesist is able to give us information of the interior of the earth which could not be acquired otherwise. The local differences in gravitational force from place to place are of considerable interest to many industries. By means of these differences and other geophysical data it is possible to locate mineral resources and to determine some types of geological substructure associ-

ated with deposits of oil. In certain regions the gravitational force is markedly different from the average. Some of these regions are subject to frequent earthquakes. The system of geodetic mapping of this country enables one to ascertain the magnitude of earthquake-movements; it also reveals gradual deformations taking place in the earth's crust which in a number of cases appear to be the precursors of earthquakes.

Seismology

While man may modify climate by encouraging certain forms of vegetation, may stem floods by the construction of dams and may transform deserts into fertile valleys by irrigation, it does not seem possible that he may ever prevent those tremors of the earth which wreck even the stoutest of his structures. However, progress in seismology has done much to mitigate the disasters which attend earthquakes. Investigation of the nature of the movements during earthquakes yields information as to the type of building which will suffer least during such a disaster. Regions which are most subject to earthquakes have been mapped out and the active fault-lines in inhabited

Photo by courtesy United States Coast and Geodetic Survey.

GEODETIC OBSERVER ON PEAK IN THE ROCKIES

PRECARIOUS POSITIONS MUST BE OCCUPIED TO PRESERVE INTERVISIBILITY BETWEEN ADJACENT GEODETIC STATIONS. BENCH-MARKS HAVE BEEN ESTABLISHED ON MANY OF THE HIGHEST MOUNTAINS IN THE UNITED STATES FOR FUTURE REFERENCE IN MAPPING.

regions are well known. The accumulation of authentic data is now permitting insurance companies to establish rates for insurance against earthquakes on a more rational basis than hithertofore. Attempts are now being made to discover conditions which may indicate a future earthquake before it occurs—measurements of gradual tilting of rocks and of slow displacements of the land.

Knowledge of how seismic waves are transmitted through the earth's crust has found useful application in the investigation of geologic structure. By setting off explosives buried in the earth and recording the echoes of the explosive wave as it is returned from the various underlying strata, it is possible to ascertain their nature and depth. This is one of the most effective methods for discovering hidden mineral resources. It has also found application in mapping sub-crustal rock-structure for highway construction and other engineering projects.

Volcanology

Man may never hope to extinguish the apparent fires of Vesuvius, but one may imagine how different would have been the history of Pompeii and Herculaneum had modern volcanological knowledge been available to the inhabitants of those ill-fated cities. To-day observatories are maintained on several volcanic cones which reveal the mumbled threats of the subterranean forces against the people who dwell in the region.

Accurate prediction of volcanic eruptions is not feasible at the present time. But since many volcanic regions have proven favorable for human habitation, the hope of accurate prediction leads volcanologists onward. The behavior of certain volcanoes has been so intensively studied that nearby dwellers sometimes may be warned of impending disasters. To foretell the exact time of an eruption may never be possible, but certain premonitory signs such as changing character of neighboring hot springs and fumaroles, and especially increasing intensity of subterranean noises, systematically watched, frequently give warning of impending disaster.

The claim is now made that an active eruption in any well-known volcano can

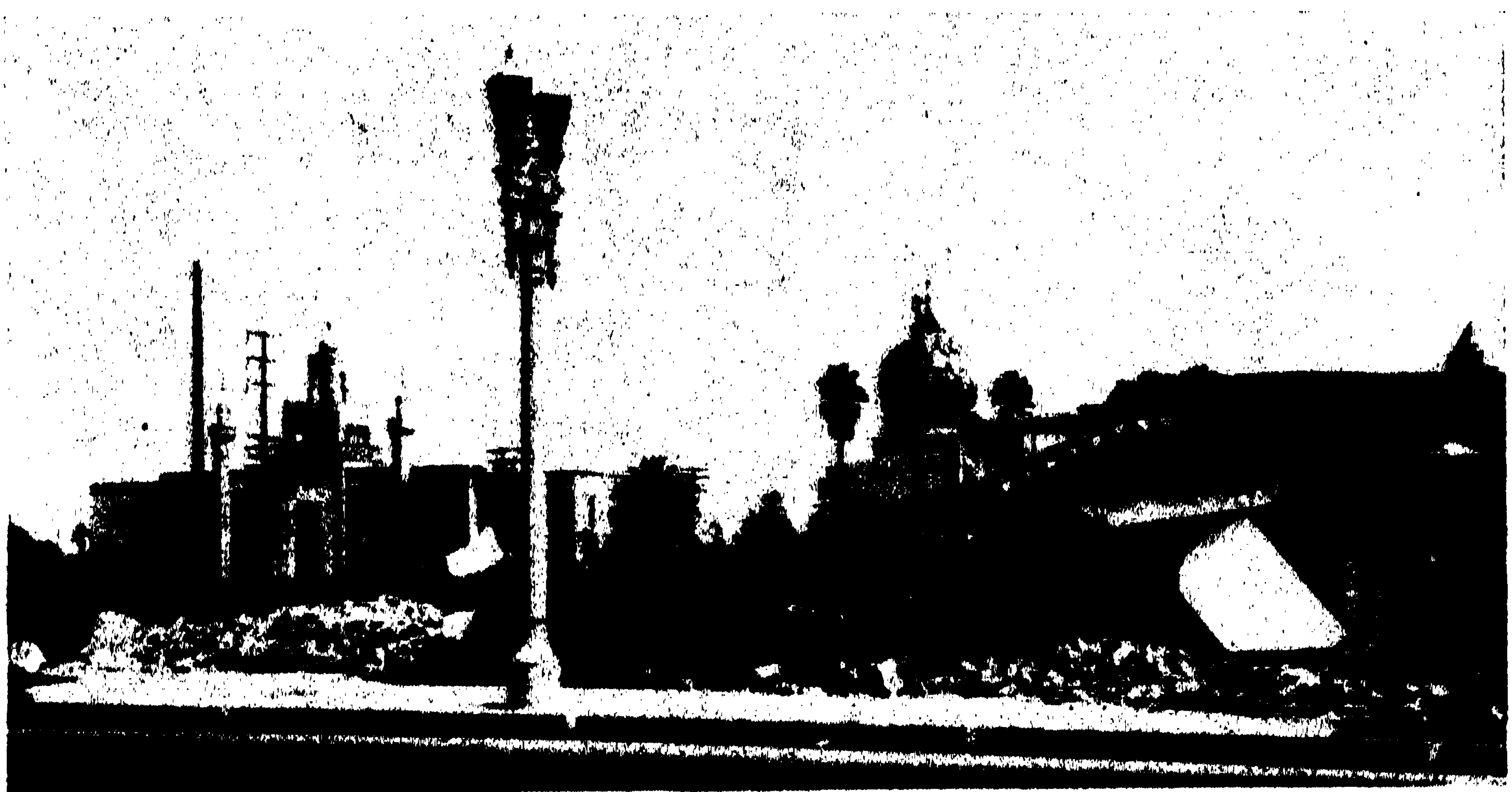


Photo by courtesy Portland Cement Association.

SURVIVAL OF THE FITTEST IN THE LONG BEACH EARTHQUAKE

MODERN STRUCTURES OF EARTHQUAKE-RESISTANT DESIGN WERE UNDAMAGED IN THE DISASTROUS LONG BEACH EARTHQUAKE WHILE BUILDINGS OF ORDINARY CONSTRUCTION WERE LEVELED. ALTHOUGH THE EARTHQUAKE SHOCK WAS NOT USUALLY SEVERE THE ALLUVIUM UPON WHICH LONG BEACH WAS BUILT SHOOK LIKE A BOWL OF JELLY. BUILDINGS IN SUCH REGIONS REQUIRE SPECIAL DESIGN.

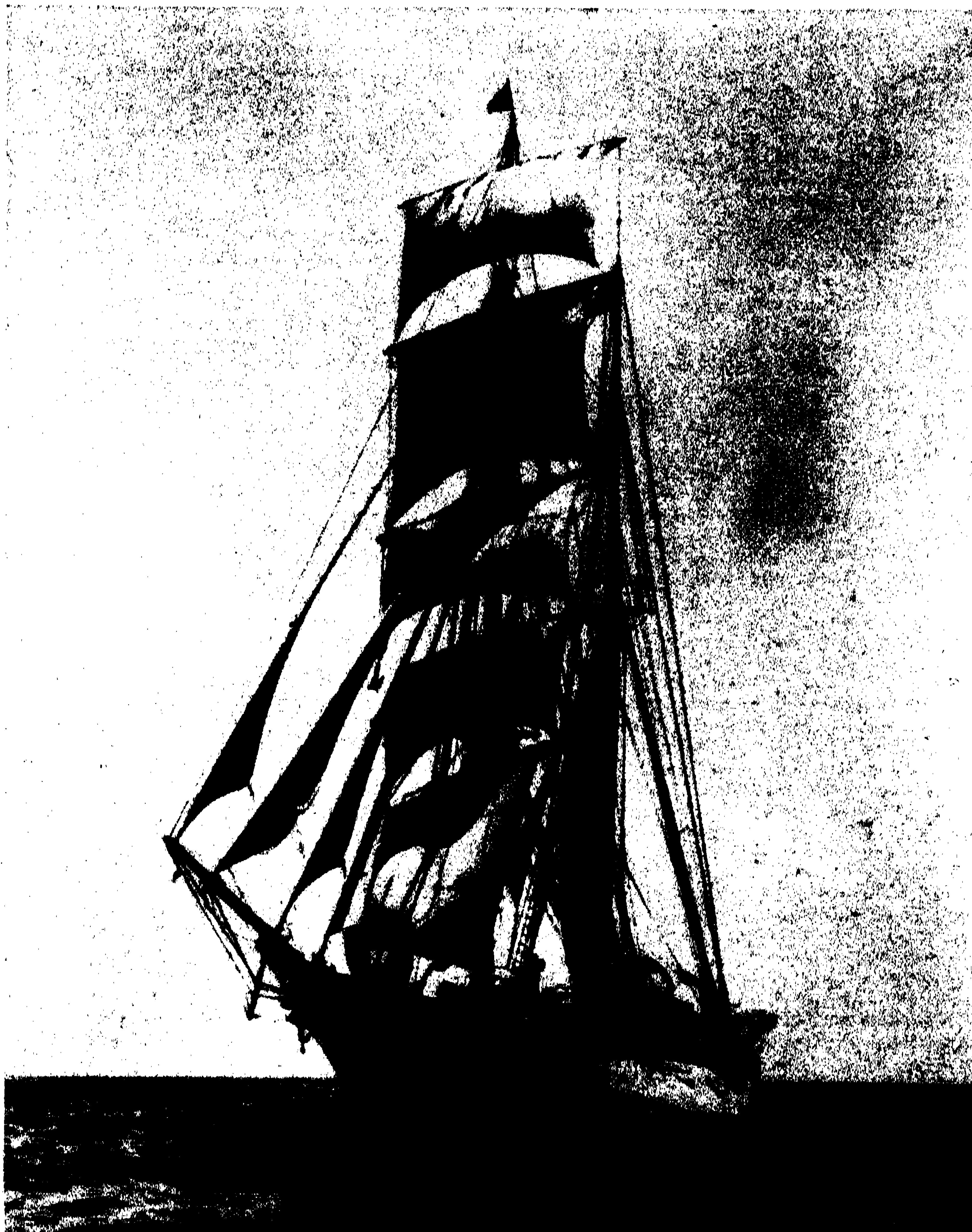


Photo by courtesy Department of Terrestrial Magnetism, Carnegie Institution of Washington.

THE MAGNETIC SURVEY VESSEL *CARNEGIE*

CONSTRUCTED ENTIRELY OF NON-MAGNETIC MATERIALS SO THAT HER SENSITIVE INSTRUMENTS WOULD GIVE ACCURATE READINGS, THIS VESSEL CRUISED 250,000 MILES TO DETERMINE COMPASS-DIRECTION AND MAGNETIC FORCE IN VARIOUS PARTS OF THE WORLD. OBSERVATIONS OF ATMOSPHERIC ELECTRICITY, COSMIC RAYS, WEATHER AND OCEANIC CONDITIONS ALL OVER THE GLOBE WERE ALSO INCLUDED IN THE SCIENTIFIC PROGRAM INTERRUPTED BY HER DESTRUCTION BY FIRE IN 1929. THE BRITISH ADMIRALTY IS BUILDING A LIKE VESSEL TO CONTINUE THE *Carnegie's* WORK.

Photo by courtesy of the Geophysical Laboratory, Carnegie Institution of Washington.

MOUNT LASSEN IN CALIFORNIA AFTER ERUPTION OF 1914

THIS IS THE ONLY VOLCANO WITHIN THE BOUNDARIES OF THE UNITED STATES WHICH HAS BEEN ACTIVE WITHIN THE MEMORY OF LIVING MEN. MANY SQUARE MILES OF FOREST DEVASTATED BY EXPLOSIVE ERUPTIONS OF THIS VOLCANO TESTIFY TO THE NEED FOR VOLCANOLOGICAL STUDIES IN THIS COUNTRY.

be diagnosed by an expert in a comparatively short time, the results enabling him to determine whether its intensity is declining or whether further dangerous outbreaks are at hand. A half-dozen such predictions of volcanic outbursts in Japan, Italy, Martinique and the Azores have proved correct. If these criteria are shown to be of general application, they are obviously of the greatest importance to mankind.

But these Cyclopean monsters, so terrible in their angry moods, are not wholly lacking in virtue. Volcanoes are sources for many valuable minerals which they yield up quite readily. In a few cases their power may be harnessed to serve man's needs. In Italy superheated steam of volcanic origin is used to drive turbines and generate electricity. At the same time volatile volcanic products accompanying the steam, especially boric acid, ammonia and carbon dioxide, are recovered and they and their derivatives are sold in the market. Hot springs, another phase of volcanic activity, produce water of recognized therapeutic value, while the warm waters from the springs in Iceland and other places are coming into use for heating buildings and other purposes.

Terrestrial Magnetism

The progress of navigation on the high seas resulting from the development of the mariner's compass forms an interesting chapter in the history of civilization. Although to-day large ships carry gyrocompasses and flights of airplane are frequently directed by radio beacons, the old-fashioned mariner's compass is still used to aid navigation, and for less pretentious modes of travel in smaller vessels absolute dependence is placed on it. Definition of boundary-lines in terms of the compass requires knowledge of the exact magnetic bearing over the land. Since the compass does not point truly north, except in a few places, and since the deviation of the compass from true north changes from year to year, it is necessary to know the error of the compass at all places on the earth and the rate at which the error changes from year to year. Unfortunately the investigations of these phenomena have been limited to too short a time for an accurate prediction of what the compass-direction will be at any one place at any given time in the future, if it is predictable. Continued determination of direction of the compass at many widely distributed places is therefore necessary.

Apart from its application in determining direction, study of terrestrial magnetism is important because of sudden disturbances of the magnetic field called "storms." These storms, accompanied by flashes of auroral light in the polar sky, play havoc with radio communication. Daily observations of terrestrial magnetism which have been conducted for nearly a century have revealed the idiosyncrasies of these magnetic storms so that a basis for their prediction has been developed. The likelihood of a magnetic storm occurring is taken into account in scheduling international broadcasts.

Magnetic storms are due to conditions on the sun as attested by their correlation with sunspots. But since magnetic storms sometimes occur when no spots are visible upon the sun, it must be recognized that the magnetic storms indicate changing solar conditions which are not otherwise observable. In astronomical language, our sun is a "variable star." When one considers what has happened to some stars in the sky—tremendous explosions or sudden shrinkings to practical extinction—he must be aware of the importance of keeping track of the behavior of that one heavenly body upon which terrestrial life so intimately depends.

The small differences of magnetic force from place to place which complicate the compass-charts have their useful aspects. They enable the geophysical prospector to define the underlying strata by their effect on the magnetic force at

Photo by courtesy Amundsen Arctic Expedition.

AURORAL DISPLAY OVER THE ICE-BOUND ARCTIC SEAS

STUDY OF THE AURORA IMPROVES OUR KNOWLEDGE OF THE UPPER ATMOSPHERE WHICH HAS IMPORTANT BEARING ON RADIO COMMUNICATION AND OTHER TERRESTRIAL PHENOMENA. GREAT AURORAL DISPLAYS ACCOMPANY MAGNETIC STORMS WHICH INTERFERE WITH COMMUNICATION BY RADIO, TELEPHONE AND TELEGRAPH.

the earth's surface. Already this means has been employed for locating places where oil and other mineral resources may be found—a far cheaper method than digging into the earth or running bore-holes through many feet of rock to discover the treasures which nature has so carefully hidden from us.

Terrestrial Electricity

Magnetic research has led to the investigation of natural electric currents which flow in the earth's crust. Their effect upon pipe-lines and other extensive metallic structures imbedded in the earth has received much consideration. How to avert their effects on the corrosion of the metals is a study in itself. Closely related to changes in the earth's magnetism, these earth-currents have strong effects on telegraph and telephone lines during magnetic storms, frequently putting them out of commission.

Since the substance of the earth con-

ducts an electric current, though not uniformly, geophysicists have become interested in the electrical resistance of various types of soil and rocks. To measure the resistance of the soil it is not necessary to remove it from its place, however. Methods have been devised for measuring the resistance of layers many hundreds of feet below the surface. Since rocks of various types, dry soil and water-levels all have different resistances, it is possible to apprehend the composition of various layers beneath the surface by measuring their resistance. Thus the geophysical prospector is able to detect the presence of mineral deposits, locate water-levels and define bedrock for the engineer who would tap these natural reservoirs or build his structures upon firm foundations.

Atmospheric Electricity

Man has been aware for all time of certain atmospheric-electric phenomena. He has seen the lightning strike with devastating effect. Fortunately, lightning hazards are avoidable by the application of modern science. The crude lightning-rod invented by Franklin furnished adequate protection in its day, but the present development of lengthy electric power lines requires a protection based upon a more comprehensive knowledge of the electric phenomena of the atmosphere.

Even during fair weather, atmospheric-electric phenomena manifest themselves. The study of the electrified particles in the atmosphere has attracted considerable attention, particularly from the viewpoint of their effect on human health. Closely connected with this study is the consideration of atmospheric pollution poured out by our large factories with their threat against human well-being.

The applications of geophysics promoting the general welfare of mankind are legion. That so many uses for the facts of the science have already been found suggests that there are many more which the further specialization of modern life will discover. Matters which a decade ago were considered purely theoretical have found many practical applications in the present. Furtherance of geophysical science, both theoretical and applied, will earn as creditable a reputation in the future as it has in the past. A thorough understanding and a sane exploitation of the earth is essential lest man in his own folly make this planet no longer habitable for the human race.

THE MEANING OF MEDICAL RESEARCH[1]

By Dr. ALFRED E. COHN

MEMBER OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, NEW YORK

You may expect from me a description of discoveries, dramatic and exciting perhaps; of new diseases or of the mechanisms underlying diseases already identified; of new drugs which cure, like sulphanilamide; or of new operations which relieve or prevent devastating conditions. I could enliven this report by such narratives, as for example the great new insights which have resulted from studying the pituitary gland seriously. The investigation of this organ by Cushing who gave the forward movement a great impetus and by many other very capable and ingenious investigators, has resulted in the description of new ailments, has given point to the attempt to understand the interrelations of fluids and tissues and organs, in ways and to extents not dreamed of ten years ago; has made available agents of real power in adjusting defaulting or erring mechanisms. Or in a sense less pathological and more physiological, describe how great has been the increase in knowledge of the behavior of such important tissues as muscle and nerve. To speak of any one adequately would cost all my time. There are other ample provisions, however, for spreading that sort of information. My task is both simpler and more complicated. I am to speak of what research in medicine "means," what its nature is and what its purposes. And I take that to include an inquiry into its position in the complicated matrix of our social structure.

The ultimate meaning or purpose of medical research is to rid men of diseases, to protect them from maladies with which they are threatened, to relieve them of discomforts once they are established. There are many diseases, differing in the degree of dangerousness, differing in nature, differing in geographic distribution. There are pathological states to the existence of which we are sensitive—others which, for various reasons, we ignore. Then there is the character of education, having its sources and momentum in the contemporary scene, which makes men fit to undertake chiefly what is comprehensible in that scene. Researches are delayed because points of importance are missed, scholars being unprepared to comprehend them and to seize their opportunities. Researches are sometimes hurried, wasteful and erroneous, because the idea is entertained that current equipment is adequate to deal with particular problems. The question of public versus private scholarship is important—less important now when the whole situation of research is better understood, and when private scholarship is recognized as being less private than formerly. Private refers both to financial resources sufficient to free scholars from the restrictions imposed upon the use of public funds; and to intellectual latitude which makes room for personal vagary, for unorthodoxy, which may not be tolerated even in an academic environment. But greater in importance than either, because essential, is the pervasiveness of current belief and opinion, current social need, the implications in the current social scene, which tend to influence or perhaps better which do not permit us to escape current intellectual compulsions. These are aspects of the

[1] The third lecture to the laity (1937–8 Series), delivered on November 24, 1937, at the New York Academy of Medicine.

intellectual life of which Hessen and his followers have made us aware.[2]

The meaning of medical research must regard these various social and personal aspects. It must regard also the nexus which exists between medical and other sciences. It must make an effort to understand likenesses and differences which characterize medicine in relation to those other sciences. It must analyze the situations, diseases and social pressures, to which energy is devoted and must describe the means, in men and facilities, which are available for carrying them out.

I propose to speak first of *what* we study; second of *how* we study it; third, of *who* does the studying; and finally in the course of this discussion *for what reason* does the study take place.

When these far reaching issues and conceptions are being canvassed there must first be described certain situations which the world of diseases presents to investigators. It has already been suggested that these vary with time and place. We do not study those diseases which do not exist—or which exist elsewhere, or which exist no longer. The impulse to study a given disease or a given hygienic circumstance results from the danger or the damage which its presence causes. Epidemics of diseases like the black death or of poliomyelitis, or of influenza, or of cholera can scarcely or safely be ignored. But not many of the resources of this community are devoted to yellow fever or kala-azar, or African sleeping sickness. If these diseases were, by their maritime introduction, to threaten the local population, a study of them would be inescapable. They are studied though for several reasons; a general philanthropic motive; because, as in the opinion of Dr. Albert Schweitzer, restitution should be made by a people for the injury done another; because, to study them is imperative to preserve health along international trade routes. Pressure of some sort is usually experienced or is exercised when a study is undertaken.

Of the diseases which we do study, there are several kinds. It is of very great importance to understand that diseases can not, all of them, be regarded as forming a system. They can be grouped, as indeed they are, to form several systems. The various systems have, superficially at least, little in common except that they transform the individuals whom they afflict.[3] Each group, on the other hand, exhibits traits which leave none or little doubt as to the relatedness of the members.

The center of gravity of interest in diseases has long, roughly for two generations, lain in *infectious* and *epidemic diseases*. To understand them and to cure them, the sciences which needed to be and which were and are actively cultivated are bacteriology and parasitology —these two in some respects similar. More recently diseases resulting from viruses, agents of far smaller dimensions than bacteria, have been added to the list. These diseases all depend on the invasion of animal and plant organisms

[2] It would be interesting and important to study the nature of social pressure, using this term in its widest sense, in the province of diseases. It is a point of view not strange to historians and students of social phenomena, but one not yet much employed in medical thinking. The illustrations in this essay have been drawn chiefly from communicable diseases and from a few other maladies differently grouped. But the relations exhibited by the development of knowledge of nutrition, or of understanding chemical processes on which nutrition depends, of agricultural growth, of social change in which the demands on the food supply of the less favored receive more sympathetic recognition—all these are matters which lie for analysis at the door of the critic. Here, as elsewhere, these and other factors require study in a complete account of the processes at work in a community.

[3] A disease is not an "entity"—it is a transformed organism. The organism is conditioned for exhibiting disease by processes which dispose it to this exhibition. The preparation may be constitutional or psychological or local—but the transformed organism is transformed, not solely by what is called an invader.

by these agents. Parallel with bacteriology and parasitology, sciences roughly grouped as immunological have been developed, in which there have been studied the reactions, that is to say, the behavior of the hosts, plants and animals, which the infectious agents invade. Studies of immunity have gone farther though than the study of individual hosts when under attack. A science of epidemiology has grown alongside the other sciences in order to study the conditions in which societies of men, animals, and plants, chance to become prepared for invasion by infecting agents. These include external factors—climate, race, season, sunlight; and internal factors, the blood, the plasma, certain organs and tissues, heredity. To cope with these invasions, efforts in various directions have sedulously been made—with sera, which utilize the forces animal bodies themselves prepare for their protection; with chemicals, like salvarsan, like optochin, like arsphenamine, sulphanilamide—all synthetized with the utmost chemical skill; with natural pharmacal agents, chaulmoogra oil, quinine, salicylates. These are, in a sense, beginnings, the success of which points to the fact that the way of thinking about such problems as they represent, is sound and therefore encouraging. Much more may be expected from such efforts. Indeed, not more than auspicious beginnings have been made.

A point of importance, later to be referred to, is that the successes, still in many instances not more than partial, have been attained by delving below the surface of naturally existing phenomena, of appearances, to learn on what these diseases depend. The rewarding results have been that bacteria have been found, and protozoa and viruses. With this kind of knowledge as a background, substances of many sorts were and are being sought, to oppose the action of the invaders. Here are the rudiments, I may mention in passing, of analytical procedures. They represent something new in the study of diseases. Compared to the amount of energy which has been expended, the success so far achieved has, quite obviously, been extraordinary.

Infectious or contagious or epidemic diseases have often been characterized as acute. Acute means two things—that individuals are seized suddenly with disability, a matter of hours or minutes; and also that their duration is usually brief—though there are numerous exceptions, as tuberculosis, syphilis and leprosy.

But there are long drawn out ailments, often called *chronic*, which fall into two great groups. Certain ones occur at all ages, like pernicious anaemia or diabetes mellitus. But there are others which befall older persons exclusively. I designate these, "ailments" and not diseases, nor yet degenerative—two words often applied to them which I prefer not to use, for reasons which I hope later to develop.

To distinguish diseases merely according to their duration is a crude conception. But to do so has a use, for the time being. Chronic has usually been intended to signify long drawn out. Roughly, chronic and long drawn out mean the same thing. From the point of view of patients and their families, duration is important; and from that of administrators concerned with the public health the distinction is essential. Actually what is involved is the rate at which the processes in different maladies advances. Chronic diseases or long drawn out maladies include a wide range of complaints. Their duration is to be estimated, naturally, from their beginning to their termination, uninfluenced, when such examples are available, by treatment. The group is diverse—there are, for example, the diseases of the blood forming organs—pernicious anaemia, leukaemia, thrombocytopenia; there is cancer, there is tuberculosis; there are the deformities of the joints; there are cardiac and arterial de-

rangements; there are the defects which result from insufficience or mal-function of the glands of internal secretion—the hormones in short; there are diseases of the nervous system. It has been customary to divide diseases into three, or perhaps better two, main groups as I am doing; bacteriological and physiological both, but the latter especially employing physical and chemical techniques. Chronic diseases fall into each of them. These categories require in certain instances to be stretched fairly wide, in order to include all the varieties. But they will serve for this discussion, especially if in studying bacterial diseases, the behavior of the host, immunology, is included; and if in the physiological ones, anatomical defects and malformations.

It is sufficient, I think, to suggest that medicine deals with many kinds of conditions and that they fall roughly into the categories that have been indicated. Of chief moment is that the classification, though rough, suffices to indicate that well characterized groups can be recognized and that, through this possibility, study is facilitated, perhaps made possible.

Now it is generally understood and indeed it must be obvious that when a malady or any other natural phenomenon begins to be *analyzed* (analysis being the method essential to experimental research) very soon a level of organization is reached, less complex than the native state of a whole plant or animal, the study of which requires recourse to a chemical laboratory. This is due to the fact that biological mechanisms, when the attempt is made to view them more simply, break down promptly to chemical processes. In physiological diseases, especially those of the heart and arteries, in parallel fashion, a stage is reached when mechanical and physical appliances are needed to help in understanding what is going on. To turn to chemistry, to mechanics, to physics, is to turn not so much to fundamental things as to machinery which underlies and which determines more complex, directly observable behaviors. These disciplines —physics, chemistry, immunology—constitute the techniques which are used to analyze, to reduce to simpler, more easily understandable mechanisms, the surface appearance of maladies. The fact that this is the situation in research in diseases constitutes a dilemma. To this problem it will be necessary to return.

I have referred to *two kinds of chronic diseases*—one which can occur at any age and one which is characteristic of the aged. Those diseases characteristic of the *aged* require especial description because, though they are not new, they are beginning to take on new significance. We grow older, all of us. As is well known, in the course of doing so we fall subject predominantly to several distinct kinds of disabilities. I pass over cancer; its nature and its ravages are in every one's mind. But what happens to the heart, the arteries, and the kidneys, has been less clearly appreciated. I do not wish to discuss all the possibilities, all the theories. One theory ought I think to be more fully described. In the sense that everybody ages, aging has come to be looked upon as a natural phenomenon —natural as differing from accident or from chance. Since every one ages, aging is anticipated and the separate phenomena of aging are looked upon as predictable. This has been a subject of very active research in recent years. And the objectives in such researches have been twofold; first, to ascertain as precisely as possible a picture of what actually takes place and second, to discover what mechanisms are at work to bring about such results. I single out the arteries for more detailed description. That the arteries change is now universally known, especially the great artery of the body, the aorta. What is less well known is that the smaller ones do also. Arteries which have come in

for marked attention in recent years are those of the heart—the coronary arteries. The walls of arteries may be thought of as having layers or coats. In the coronary arteries, for example, the first detectable changes take place in the innermost layer; its elastic membrane splits in two and does so rather early in life—in the twenties. From then on, more and more changes take place. At 50 or 60 these changes are advanced and have been termed arterio-sclerosis. To one familiar with the succession of these appearances, it is possible to tell their age within a few years. Being able to do this is good evidence that there is nothing haphazard about the process. How are these systematic changes brought about? And how, assuming that they develop systematically, can they be prevented or delayed? To answer these questions, guesses have been ventured since very early times and to explain them, serious, far-reaching researches have been undertaken. But so far there are no answers satisfactory to many scientists. Meanwhile the quest goes on, with intensifying earnestness. The problem, as I shall show presently, is urgent. What is true of the arteries of the heart is true of those of the brain. About other organs less is known. Progressive alterations, appropriate to each organ and tissue, go on throughout the body—beside the heart muscle, in the kidneys, in the liver—everywhere in short.

But changes in structure do not alone exhibit progressive alteration. Comparable ones can be observed also in the functioning of the body. The slow and gradual rise with age which the blood pressures exhibit are well known. Another striking one has recently been found in the nutrition of the body. Here, it appears that ptyalin, the starch-splitting ferment of the saliva, decreases between 25 and 81 (these are averages) to one thirty-fourth, necessitating, it seems probable, a very striking readjustment in digestion and food requirements in the aged. More intimate still are changes in behavior of the muscle fibers of the heart. It has been shown in dogs, for example, that as the animals grow older, the ability of this tissue to utilize oxygen diminishes significantly. Finally, as in changes in structure and in function, so also, it appears can changes in psychological performance be detected. Interest in this phase of growth has begun more recently, so that it would be rash to accept the results of preliminary studies. There can be little doubt though that this is a fruitful field for further investigation.[4]

Many regard it as an idle question, but it is one which should be put nevertheless—are processes so universal as are those identified with aging to be classed with diseases? Diseases are not constant; they wax and wane; new ones occur; old ones vanish; they are unlooked for; they are recovered from. Of the changes which accompany aging, none of these characteristics can be predicated. It seems better to weigh the question of the nature of this process of aging a while longer, before coming to a decision on its nature. Two ways of thinking are possible—that aging is an accident which can be prevented; or that it is not an accident and that, as the body increases in bulk and by so doing is said to grow, parallel changes are taking place within the body, in its most intimate recesses, which accompany that growth, and which themselves may be regarded as taking part in and perhaps constituting the phenomena of growth. In this sense the body grows continuously, changes, called differentiation, taking place in all its parts, the form of change passing from

[4] This reference to psychological matters is brief because I am depending on other phases of this problem for illustration. But the place in human nature and in diseases which psychological deviations occupy can scarcely be overemphasized. I am at one with those who wish to understand organisms as wholes and to return from the wilderness into which the requirements of thought in the 17th century naturally led us.

stage to stage without break until the final dissolution. This view urges that there is only one forward moving change —not, first growth and then degeneration, but continuous progressive differentiation. And growth so understood is not an accident, it is not degeneration—and it is not disease.

These old ailments present a new challenge. To care for them is becoming a great burden, financially. Can anything be done to relieve the strain? Medical research, not yet very consciously, is struggling with the question. It has no settled answer. When such questions were first raised fifteen years ago, we were not yet ready to weigh them. Now the response may become, is indeed becoming, more intelligent. The old hospitals built for infectious diseases will no longer serve. In part they are improperly constructed for these purposes. And from the point of view of research, the new situation calls for new orientation. It is still inescapable that research in infectious diseases continue here and elsewhere. Here because there is still tuberculosis, syphilis, poliomyelitis and other infections of the nervous system, rheumatic fever and influenza; elsewhere, in the tropics, because of diseases indigenous there, but perhaps transplantable here. But since the dawn of that era in which we have spent our lives, the emphasis has been almost exclusively on diseases of this kind. It would be incorrect to say that diseases longer drawn out at older ages had been neglected—cancer for example or cardiac diseases. But it is certain that in comparison with infectious diseases, they have been much less cared for and studied. The great desideratum now, is to turn increasing attention to these conditions. If they were better understood, it might become possible to manage them better. If they were better treated, expensive care in homes, and in institutions might be less necessary; if they were less expensively treated, the burden of taxation might diminish. The net result would accrue vastly to the sufferers themselves—in increased health, in greater freedom spent outside of institutions, in greater economic self-sufficiency. Psychologically, the lives of older men and women might be re-made if we learned how to make them self-sufficient to a degree impossible now, through a new orientation to employment, utilizing opportunities for activity appropriate to the aged. Embedded in the matrix of our society, no better fate is provided for them or envisaged than progressive deterioration.

I have been speaking of *what* we study. I come now to speak of *how* we do so. After long reflection and practical experience there has come to be general comprehension of the purposes and methods of the sciences in general. By the same token, a similar statement can be made of medical science. But in some subtle way, there is tacit agreement that the two are in essence, somehow different. Whether they are, depends I think upon the aspect from which this judgment is made. They do not differ, there would be general agreement, in attitude to natural phenomena; nor do they differ in the seriousness with which the problems of diseases are studied; nor do they differ in the methods which both, or all, use. To recognize and to point out differences is not invidious; no more is intended than to understand a complicated situation.

Two suggest themselves—first, one having to do with the nature of the subject matter—and second, one having to do with the circumstances conditioning the activities of students of diseases. The former difference, in subject matter, has, I venture to believe, a certain validity[5];

[5] It is perhaps a superficial experience but one to which large numbers of persons are sensitive, that in a very general sense, diseases are ugly, repellant, offensive. These are not qualities which characterize phenomena studied in other sciences. The reverse may and often is true. It is of course a fact that to many men, perhaps especially to physicians, this aspect of disease is without meaning. It may be that to them the

the second, I think, not. To begin with, though it is not my intention to become involved merely in words, it is well to make clear the meaning I ascribe to certain terms.

Science, very briefly, is a way of looking at nature, in so far as that is possible, exactly. Two aspects are involved—the natural phenomena themselves and a way of looking.

Research is procedure. Research represents the effort men make to increase their comprehension. To discover what is true about anything is an arduous undertaking because, at the outset, so many things seem possibly correct. That is why research is an adventure.

The object of the whole enterprise is to *describe* nature.[6] At first it seems wise, at all events it seems to have been universally customary, to describe natural phenomena so as to group them. That makes description easier because there result fewer descriptions. Classification is what this phase of the undertaking is called. Sometimes, especially in our day, there lurks unfortunately, something invidious in the remark that an investigator is merely "describing." Descriptions must naturally be exact. Exactness can in fact be exhibited, purely and deliberately, without quantitative expression, in descriptions of things as they occur in nature, rough and in the whole. Men who have carried on this phase of natural enquiry have been known as naturalists or, at a stage more organized, more complicated, systematists. Hippocrates, Pliny, Linnaeus, Sydenham, Darwin, Lyell, Audubon, Wheeler, form such a group. Their very names are proof that nothing derogatory attaches to their interests or their methods. Without labors like theirs, there can be no natural science. Without them we should be talking of phoenixes, unicorns and other mythological animals. It is an evidence of the literalness of the culture of the Greeks that, unlike Egyptians or Orientals, they entered little into nature faking. The objects of concern to scientists have been natural objects. Later—and later may be taken to have a chronological meaning, though it may have also a logical one—when the *experimental era* began in its modern form, reliance came to be placed, not by any means exclusively but accompanied by a certain glamor which obscured the relations among methods, on the experimental method. A powerful agent for extending knowledge became available. The experimental method involves the conception that comprehension of a thing, of a phenomenon, can be furthered powerfully by dissecting it, by pulling it apart, by measuring and by weighing and by counting.[7] I need not dwell on, what is universally known, the extraordinary and unbelievable success of the method. By it Galilei, Harvey, Newton, Young, Lavoisier, their modern equally great successors and an enormous host of followers have enriched modern thought, modern knowledge and modern life.

When the experimental era began in its modern form, the temptation was great to believe that, once the parts were known, the whole would be comprehended. It was another way of thinking

very fact of ugliness has the value of attractiveness. Nor need this be regarded as odd. The last word on the subject of ugliness has not been uttered—in sight, sound, or form.

6 There are those to whom action appears a more impressive and compelling motive than description. The object of the enterprise would then be to accomplish an end. The difference may be essential but it may also be a difference in emphasis. If astronomy began in the interests of action, it has remained a means to satisfy mere curiosity; or—is it perhaps to return to its original function?

7 It needs scarcely to be pointed out that what is called synthesis, as in the preparation of chemical substances, dyes for example, or aromatic compounds or in metallurgy when new alloys are made or in technical procedures or advances in general, is an extension merely of the analytical process.

that the whole is equal to the sum of the parts. But doubt began to assail thinkers that matters were not so simple. It was the same situation that confronted the King's horses and the King's men when they tried, after his great fall, to put Humpty Dumpty together again. The attempt did not work. Because it did not and because in a very widespread manner there is current conviction that it can not, the idea has been put forward by S. Alexander, Lloyd Morgan, A. N. Whitehead and General Smuts that, in putting things together again after they have been taken apart, something new becomes ingredient, something not in the constituent elements. It is, to use a crude example, as if $2+2$ did not quite equal 4—that to attain 4, something not in the synthesizer's hands or mind, entered into the new composition. The doctrine that something new occurs has come to be known as emergent evolution. In speaking of analysis and research, it is unnecessary to lay undue emphasis on the imperfections of the analytical process, but it is desirable to be alive to their existence so as to avoid the disappointments which otherwise are almost inescapable. There have in point of fact been a goodly number. Leaving aside the emergence of new qualities, a phase after all of synthesis, the delays which have taken place in the cures of infectious diseases, like tuberculosis, like typhoid fever, like poliomyelitis, after the discovery and identification of the agents that help to occasion them, are known to everybody.

The whole adventure, classification and analysis, is science. I said it had two aspects, the natural phenomena themselves and a way of looking. Of the way of looking, there has just been discussion. Of the natural phenomena, there is something to say concerning a significant difference between medical and other natural sciences, the difference to which I wished to direct attention and which I wish briefly to weigh. It is the *enduring interest* that attaches to other natural sciences in contrast with the medical ones. Consider such interests as the origin of species, the origin of astronomical systems, matter, heat, electricity, the formation of the earth, light, heredity. These are concerns as little influenced as may be by time and place. There was never a time when they did not engage serious intellectual attention; they do so now; there is good reason to believe they will continue to do so. These phenomena awoke and continue to awake enduring interests because they are enduring objects.

Turn next to the situation in the study of diseases. I have been dwelling on enduringness in interest in the objects of natural science because the objects studied in these sciences are themselves enduring. Now diseases, whether of plants or of animals, no matter what their nature, are statistically something extra.[8] They are occurrences which, in subtle or coarse ways, change the usual behavior of living things. The organisms are said to suffer—hence the use of the word, in the British sense, pathology. Beside being something extra, their becoming established in a society is not permanent. They change with time, they change with locality. The sweating sickness is gone. How long poliomyelitis may have existed is not known. Diseases devastating in the tropics do not exist in the temperate zones. In other cases, like rheumatic fever, the reverse may be true. Diseases may continue to turn out to be transient sojourners. By paying a necessary price, there are diseases of which we can rid ourselves—syphilis for example, perhaps scarlet

[8] Extra—not anticipated in a state of "health." I do not mean that process "a" is joined to organism "b" and that $a+b$ constitute a disease. In this sense a would be what has been called an entity—an "ens." That is far from my meaning. "Extra" describes the whole organism, exhibiting phenomena, not counted as occurring in health. Health itself is a statistical conception.

fever, no doubt a number of others. Diseases, furthermore, have no independent existence; they are recognized when they have transformed the nature of their hosts, plant or animal, temporarily or permanently.

If, as I have been surmising, enduringness is a characteristic of things which have become constituted objects of study in natural sciences, it seems apparent that diseases do not partake of that quality. That is clearly the case in infectious diseases. Nor in all probability do chemical diseases, of which the deficiency states are examples, pellagra, pernicious anaemia, rickets and scurvy. Another group of diseases of great importance may be designated physiological. Physiology may be termed the study of the living behavior of an organism, as different from its mere structure. In the study of diseases, the physiology of an animal has importance because it occupies a place like the study of metallurgy in the mechanism of a steam engine. But a disease is not merely quantitatively changed physiology. A disease is something over and above and therefore different from this. The place of physiology in this scheme must not be confused. Physiology undertakes the analysis of something, animal or plant, reasonably long enduring in a species or a genus—the circulation, reproduction, digestion. These are mechanisms which are neither temporary nor local. There are of course physiological derangements which are usually called diseases, eclampsia being an example or perhaps a certain variety of arterial hypertension, or fibrillation of the auricles of the heart, or psychogenic hyperthyroidism. And a special case is that of senescence—the aging through which we all pass. My case as to enduringness is naturally not as clear-cut in respect to physiological occurrences as the distinction I have drawn suggests. Evolution and the disappearance of species and genera see to that. But there is enough of background for this distinction to occasion the social consequences in which can be perceived, implications of great importance to the position the study of medicine occupies.[9]

I wish now to examine the use of another word. The word *"empiricism"* provides an opportunity for examining certain ideas and procedures commonly employed in natural science. When a certain amount of animadversion is intended in the use of the word, the adjective "crude" is prefixed. This phrase "crude empiricism" has been used especially with reference to the study of diseases, the assumption being that the study of diseases is something apart, in fact, from other studies of natural phenomena—something perhaps a little backward. On more careful reflection it becomes clear that "crude empiricism" is a phrase universally applicable to a level of discovery at which, what is called "thinking" has not been much employed or, can not be, either in the existing state of knowledge or by the individuals who indulge in that occupation. Now, when what is called "crude empiricism" is exhibited, the subject matter under investigation is relatively in a raw native state and the means which are used to analyze that subject matter are not, in comparison with what is possible elsewhere, or in some other discipline, of a sort to be called refined. An example in medicine

[9] There is a point of view from which contributions to general knowledge result from the study of ephemeral phenomena or from acquaintance with transient experience. Contributions so derived can, no doubt, exert significant influence in developing insights, conceptions and procedures which come much later to fruition. Broad intellectual streams can originate in obscure rills. But there remains nevertheless a value which enduringness, as a method of characterization, can be made to possess. Even so, as a characteristic, it is unnecessary to assume that it has more than relative value. Were diseases dependent on a relation to bacteria wholly to disappear, bacteriology, for example, having received its great stimulus from this association, may be expected to remain an important interest nevertheless, because of the growing place it is coming to occupy in agriculture and elsewhere.

is the use of quinine in malaria, before an insight into the nature of malaria or the composition of quinine was obtained. Syphilis and mercury is another example, or dropsy and digitalis. In physical science, telephony and the nature of electricity, though a very rough analogue, may serve as example. The form in which I have stated this situation suggests its meaning. When something is done or some interference with a system is undertaken, as in the examples just given, it is in the natural organized state of the material, the crude, native state, in which the operation is performed. There exists no guide, furthermore, to suggest what form the operation should take. If malaria is not known to be protozoal in origin, or if it is unknown that the infecting agent is susceptible to quinine, but a therapeutic attempt is made, none-the-less—that attempt is empirical and may be termed crude. That it should be so is in the nature of things. If the object is to understand—anything whatever, a beginning must be (or is) made. Once a beginning is made, successive efforts at understanding, if on the road to success, become less and less "crude." In the case of matter, electricity, energy, methods of analysis have now become so refined that it is evident how long a distance has been travelled from rubbing cat's fur on amber (electron). The more we analyze, the further investigation becomes removed from crudity. Because analysis has taken place in successive simple stages; because, covering the heart of a phenomenon, there are layers of impenetrability, like the layers of petals covering the heart of an artichoke, Sherrington was moved to say, because that is the way an experimenter must look at the world, behind each mechanism is hidden another mechanism. Obviously the metaphor of the artichoke is imperfect—there is a last layer of leaves, small and apparently confused in arrangement, and then the heart. But in the phenomena to which scientists devote themselves, who knows when the last petal has been plucked and the heart of a natural process uncovered? There is a chance here (and the man who knows how to take it is the artist in science) that for *an* object, it is unnecessary—no, destructive in fact, to go further than a certain point—the point being the emergent level for which search was being made. Protection against pneumonia will not, by way of illustration, be solved at the atomic level. If the appropriate level is passed, the nature of the thing sought may elude one's grasp. Hawthorne's story of the birthmark and beauty tells the story of the devastation wrought by a perfectionist.

Whether knowledge is empirical depends often on the standpoint of the critic. A molecule, a protein molecule, may seem very refined in comparison with a man, but to an electron it looks enormously complex. The whole business is relative.

The point about empiricism and crudeness requires no further laboring. It must be apparent that at the beginning nothing else than crudeness is possible. Later on more insight may have been gained, but the term will still be applicable. Were the case of causation simple, as it is not, it would be possible to prescribe how a situation must be analyzed and possible to prophesy the results. There is little confidence nowadays that that can be the situation anywhere. Further understanding depends therefore on trial and error in the choice of analytical techniques. Since that is inescapable all scientific analysis is crude and all knowledge empirical. The only point of view from which empirical knowledge is less crude depends on the amount of relevant research that has been made. Much more has become known about malaria and syphilis, about quinine and mercury, about dropsy and digitalis, about energy and electrons. But to him who confronts a choice of the

next step, the situation contains elements of crudity which he recognizes as not far removed from that of that predecessor of his, who took the adventurous first step. So long as there are further steps there is adventure and so long as there is adventure there is crudity. Otherwise research would be a commonplace procession along the avenues of the known. The Lindberghs would be the last to underestimate the Nungessers.

He who tells us we must halt a research until analysis has proceeded further must be certain of a number of matters around which this discussion has taken place. He must know that further analysis of a complex situation is rewarding. A chemist preparing therapeutic agents will appreciate this point. Suppose it were optochin he had prepared and were told that too frequently giving his preparation caused blindness. Against pneumococci his agent worked admirably—that was his original objective. To perfect his agent and to safeguard it against unexpected, unfortunate consequences, what must he do? Must he search for other substances, similar in structure, must he try another group of agents, or must he, by analyzing optochin further, hope to discover what is offending in the structure of his drug at a different lower level of organization?

Quinine and quinidine afford another example. The auricles, the entrance chambers in the hearts of human beings, often lose their custom of orderly contraction and do what we call, fibrillate—a state in which they live and act but do so in a very disorderly fashion. A sufferer from this disorder once noticed that frequently when he took quinine, the normal behavior of his heart was restored. He narrated his experience to his physician in Vienna, Professor Wenckebach. Professor Wenckebach sought to repeat his patient's attempts but met with scant success— and told his story in one of his treatises. It occurred to another physician--Frey—to try more or less systematically other chemical substances with which quinine is related. At this point it becomes necessary, perhaps unwarrantedly, to assume certain biographical details. Was that a rational procedure of Frey's—was there good reason to think other quinine-like substances would work better than quinine; if so, which one, related how to quinine? Or should he explore other substances—not quinine but substances belonging to that series? Or should he attempt to build up quinine into a drug more complex? Or should he break it down to find what in quinine actually worked in Professor Wenckebach's patient—purify the drug in short? Or should he look for a substance which, in Professor Wenckebach's patient, aided quinine but was absent in his own? Or did his own patient harbor a substance which interferred with the action of quinine? All these were possibilities. A complete account of how Frey behaved in this situation is unknown—it usually is. He may have tried none of these or many. He had a single guide only. He was told quinine worked in a *single* person. We are speaking of levels of organization. The only point of immediate concern is whether he should have analyzed further to find a simpler substance. It may be, he should have done so, for the result of his labors has been effective in about 60 per cent. only of patients. In that sense the problem is still open and the various choices enumerated for investigation still available. What Frey did was to explore what is possible on the very level of organization of quinine sulphate. He found in the group a substance which worked 60 per cent. of the time, quinidine sulphate, identical with quinine sulphate except for its action on polarized light. This was turned left—quinine turns it right. The structural formula symbolizes the difference in that the two are written as mirror images of each other. In this case, no further analytical procedures were undertaken. Success, partial, it is true, came on a

level of organization no different from before. There was no way of knowing beforehand that this would be the case. Attention to causation would not have helped. It was not known, it is not known now, what causally is essential in this reaction. It is therefore unprofitable to search for it.

It is in the nature of things that students of any phenomenon must have first-hand knowledge of that phenomenon itself. For simple description first-hand acquaintance is all that is requisite. For analysis it is essential in addition, to possess knowledge of the art and practice of appropriate forms of analysis. There is no fundamental difference in the nature of these procedures for students of diseases and for other natural scientists. Nor is there a difference in the operations which the mind undertakes. The intellectual powers appropriate to elucidation of the two are the same, whether the object of study is a disease or an electron. The physical methods employed in laboratories naturally differ and are especially adapted to the objectives and material being analyzed. But the mind proceeds always in the same way; it knows few tricks and these few it employs indifferently wherever it has use for them. The mental act, when it comes to procedure, measures, indifferent to rational objective, length or volume or frequency. The behavior of the mind remains always the same irrespective of the tools it causes to be used in the various situations in which it acts—it describes, it classifies, it dissects. Experience must come first and then the analysis of that experience, whatever the object.

But a potential difference exists nevertheless. The practice of medicine is an ancient calling. It is as intricate as it is ancient. It is one of the nicest of the arts. Its practitioners have been in the habit of performing many social functions. These have been so absorbing that until almost contemporary time neither leisure nor opportunity nor perhaps desire was available to proceed beyond simple description, of which there has been much, to analysis[10] which has but recently, and let us hope not tentatively, begun. What needs appreciating is that the gap between practice and analyzing is by way of being bridged. The existence of the gap can not be ignored. Of its deterring effect much has been made—in my judgment much too much. When students were inadequately, or not at all, trained for research, more weight attached to the exclusive demands of practice than now. Much has changed, not least the estimate placed on traditional knowledge and on practical legerdemain, though medical opinion still insists upon transmitting a great deal of this in formal education. But in spite of all change, of persons interested in diseases, two types can be seen to emerge, one interested in advancing knowledge about them, and the other in treating them. The difference is similar to that between engineers and physicists. Physicians who wish to learn how to analyze, now can do so—and do so to extraordinarily useful purpose. But there is the difficulty I have mentioned—the gap. It is real and it is important. It occasions a difference not found, I fancy to the same extent, in other sciences having both theoretical and practical phases. Who would suppose, for example, that Graves disease (exophthalmic goiter), in order properly to be comprehended requires knowledge of physiological occurrences and chemical processes, obviously not necessarily within the competent knowledge of conscientious practitioners of medicine? Or in the kind of cardiac affection common in older individuals, of insight into and control of the most intimate behavior of muscle fibers? And not only that, but knowledge of what underlies the behavior of those muscle fibers and their ability to carry on work. I have spoken of other difficulties which beset physicians, but here is a major one.

[10] Not psycho-analysis.

To treat what is so obviously wrong, he must have learned, in physiology and physics and chemistry, what a man can learn only, if he learn it at all, as the result of the expenditure of all his energy. Research, in these circumstances, was at an impasse. For 25 years and more the effort has been made to bridge this gap by providing opportunity for a few physicians at least, to free themselves from the demands of practice. The divorce of research from demands so continuously absorbing has accomplished noteworthy results. Whether the divorce is adequate has not, I think, received sufficient scrutiny.

This much can be said safely, that time for research has been gained. And this in addition that to concentrate effort, a certain amount of irrelevant information may be left at the wayside. And finally this, that physicians who observe the phenomena of diseases receive from their intimate contact with patients and their ailments, stimuli to ferret out the meaning of what they observe. No one else has access to that knowledge. Having that knowledge and requisite training, the hope is still entertained that physicians, specially chosen, can solve the relevant problems. It would be idle to underrate the difficulties. They do not so much consist in translating problems from bedside to laboratory as from transvaluing one pattern of knowledge with its technical (clinical) apparatus to another quite different pattern with equally exacting, if not more complicated, technical (mechanical) apparatus. To recognize, for example, a cardiac disease, to think of its origin, to study its future, is obviously a different enterprise from search for the mechanism of the contraction of muscle on which its clinical manifestations depend. For that search involves far away knowledge of proteins and the part they play in the complex structure of muscle, as a result of which they contract. Other illustrations may be chosen —syphilis for example, its dependence on a microorganism—a spirochete—and the susceptibility of spirochetes to poisoning by arsenical compounds. Or still another, diabetes mellitus, depending essentially on destruction or malfunction of a single structure in the pancreas—the islands of Langerhans—and its remediability on a substance extracted from these islands.

This discussion and these illustrations should suffice to define a peculiar situation in medical science. I have already spoken of a special characteristic of the subject matter of "medicine"—the absence of "enduringness" exhibited by diseases. And now I have added illustrations dealing with the apparently wide interval between diseases as natural phenomena and the cumbersome traditional technique for learning about them, the practical aspects of this study, on the one hand; and the equipment necessary to deal with the analytical procedures necessary in research, on the other, to explain how the position of medical science and of medical scientists has come to be somewhat different from that in other sciences and how the intellectual position of medical scientists has been regarded as differing from that of other scientists.

It is, I think, impossible just now to exaggerate from a public point of view the importance of treatment. The motives which have brought great funds for study into existence have not, except in connection with great dangers, arisen from general public interest. The year 1776 was remarkable, aside from having witnessed the signature of the Declaration of Independence, for the effort Johann Peter Frank made, on behalf of the Archbishop of Speyer, to gather information on a social, political, or at all events on a grand scale, concerning the health of a population, so as to make this more secure. That adventure began an epoch. Usually, it has been the illness of a friend or a member of a family that stimulated the insistent interest of private philanthropists. The universities

had no funds. Government took a minimum interest only.

Once, when I defined medicine as the study of *diseases*, Doctor Thayer objected vigorously because in his judgment, joined inseparably to the study of diseases was the need to get on with the business of curing these diseases. The term medicine, he thought, included both. Obviously a term can mean whatever we say that it does. There is no reason against the use of the term "medicine" in the manner on which Doctor Thayer insisted. It is preferable though, I think, not to make the meaning of terms too inclusive; that is a way of obscuring the variety of aspects which a situation can be made to disclose. It is undoubted, indeed in the world of medicine, the notion is widespread, that to search out the nature of diseases is one of our chief obligations. But there is no doubt also, that the notion of curing diseases is universally believed to be a function of physicians. The function of medicine in the *cure* of diseases is so deeply imbedded in both public and professional minds that there have been periods of impatience with the belief that the business of curing is difficult and complicated (Hahnemann, etc.); with those who insisted on an education more or less elaborate for men whose office it might become to search out cures. Joining the search for knowledge of diseases with curing has, I think, tended to obscure the problems presented by both. It is not without importance to point out that to make cures provides, within properly defined limits, for a kind of activity not encountered in other disciplines.

Cures are of two kinds—we have depended on what I have been calling "crude empiricism" for one of them. Here there is no use for the refinement of analytical procedures. Agents not rationally related to complaints are used to mitigate them. Such agents do turn up, as digitalis in the case of dropsy, suggested by a Shropshire housewife who interested the willing Doctor Withering in her experiences; or when, owing to faith in the providence of God, the notion is entertained that where diseases occur, there in close proximity are their cures to be found—as salicylic acid (the willow) in the case of rheumatic fever.

The other kind of cure relies on nothing so simple, nothing so fortuitous. In this case cures are conceived possible because of a belief that there exists something in a morbid condition, central to it, a knowledge of which would further the possibility of cure, as of microorganisms in typhoid fever; or of toxins in diphtheria; or excess activity of an organ, as in thyroid hyperactivity; or deficiency in a secretion, as in pernicious anaemia; or defect or destruction in tissues or organs, exerting either immediate or remote consequences, as the effect on the heart in beri-beri, or of the late result of rheumatic fever; or, following in the footsteps of Ponce de Leon, substances which neutralize the action of agents that make the body age.

But how are such substances to be found? There must be no mistake; they are actually and feverishly being sought. The sciences of chemo-therapy, physicotherapy, immunology, pharmacology, the founding of institutes for the study of cancer and for this, that, or that other, are evidence of the liveliness of the quest. Sometimes the direction of research is simple enough—the agents being already well known; in the case of haemolytic streptococcus infections, sulphanilamide; in tetanus, tetanus antitoxin; in the failure of cardiac muscle, digitalis. But in the case of cancer the situation is different; since neither cause nor cure is known, shall the search be for an agent to combat a virus or some other substance or for the correction of a constitutional arrangement responsible for the licentious growth? The direction which the search is to take is often the subject of sharp cleavages of opinion. The single subject, cancer, illustrates how in the

process of analysis, talents, equipments, trainings of different forms may become serviceable. If you believe cancer is caused by a virus you want men to search for it who are perhaps *differently* endowed and certainly differently equipped from men who believe the solution of this problem lies in discovering a chemical substance to be neutralized, responsible for its origin or development.

To a choice of means, beside haphazard, there is no other guide but reason. But reason operates in the domain of causation and its tool is logic informed by insight, which in an exact sense is experience in action. Now, as has long been evident, reason alone is inadequate. Hope resides in the use of reason to limit the region of investigation so that then, within narrow, indeed within the narrowest framework possible, systematic trial and error can be attempted. If science is empiric, somehow experience provides it with a pattern. That is Aristotelian. Here is the inescapable region for the display of scholarship, ingenuity, resource. What the issue is to be, in seeking the cause or cure of cancer, no one now, I presume, would be bold enough to declare. It is a fortunate circumstance that men of many minds, everywhere, are engaged in this search. But the point to be made is that once the method of crude empiricism is abandoned, the alternative, which is analysis, requires technical education not at the disposal of everyone interested in a subject. The problem is the problem of the physician as scientist. Special training is the price of analysis and analysis is the consequence of the failure of the obvious.

I could have drawn this lesson on rational therapeutics from another source. It has been said, and said plentifully, that the dawning interest in ailments of the aging is the result of social pressure. Formerly that pressure was exercised, as now in the case of poliomyelitis, to secure protection from bacterial diseases, because they, often being contagious, were dangerous and required quarantine. Comparable pressure is being exercised now because the ailments incident to older age are long drawn out and tend to be costly—indeed very costly. The study of statistics created awareness of this situation; deaths from certain causes were increasing. In the course of a few years a general conception of what this meant began to be clear—or clearer. Little was known. The study of aging began then in a more serious fashion.

The problem what and how to study is not, in some respects, unlike that in cancer. What causes aging? Is it necessary or preventable? If preventable, does it result from subtle injuries inflicted in the course of ordinary living—injuries due to infection or diet or to other environmental moments? Where is evidence to be sought? In changes in the arteries or in some other tissue or organ? Is its cause a substance secreted within the organism—constituting a master reaction—not by design, though that is not an unusual conception, but because of its fortuitous and unavoidable nature? If aging is the result of any of these causes, obviously means to bring the process to a standstill can conceivably be found. But if it should turn out that it is none of these or none comparable to them, that aging is universal, it will be necessary to turn to the notion that aging takes place in the nature of things, that somehow it is incident to living, an expression of the togetherness of the organism, not a follow the leader mechanism; that the disabilities and ailments to which it gives rise call for alleviation of disability and suffering, different—or perhaps not different—from those that are sought on the assumption of preventability.

From the point of view of research, the meaning is clear. The resources of intelligence are wanted badly in this situation—natural historians, statisticians, morphologists, chemists of several sorts, physiologists, physicians. There may be

short cuts to discoveries in this category, but the history of science does not encourage us to expect to find one. It is more likely that in order to learn what to do, it is necessary first to search out the forces that are at work, and the precise forms they assume. Attempts to anticipate solutions by short cuts have too often been futile. We are, naturally, not told that enough is known to make a solution possible. And then it is no longer believed widely that genius can advance far beyond current knowledge. Newton, for example, is unthinkable as a contemporary of Aristotle. Failure in scientific research is often the natural answer to premature adventure. The frequency of simultaneous discoveries is evidence for the correctness of this view. Pressing on the door of the unknown is nowadays constantly taking place. But we do not believe we know beforehand who will force an entrance. We believe, therefore, in freedom of research—one of the academic freedoms which ought accordingly, sedulously to be preserved. Whether a research can be made to pay is a matter of judgment. Who has this judgment? Experience counts of course, though the inexperienced, like Parsifal, often see the light. But Aristotle, Harvey, Young, Helmholtz, Pasteur, Hering, Ludwig, Gaskell, Darwin, to name only biologists, were not inexperienced. Since chance enters the calculation, there is little room for dogma.

The clinic has been an integral part in the scheme for providing for the care and study of patients and their ailments. The very fact that clinics present the opportunity of seeing and comparing the manifestations exhibited by patients has facilitated greatly, as Shryock has pointed out, the description and classification of diseases. To be able to do this is, as we now know, indispensable in the development of scientific knowledge. When the stage of analyzing the appearances of diseases is reached, the equipment possible to clinics is essential. Equipment includes, for example, laboratories for chemical analyses, for the study of the physiological and physical aspects of diseases, for bacteriology, serology, immunity, haematology. In the past 100 years, but more especially in the past 30, such opportunities have actually been provided on a fair scale. It has become possible for physicians to study whatever phase of a disease seems important. Naturally clinics do not neglect the management of patients. On the contrary. They exist for the sole purpose of encouraging better and proper treatment, as adequate as contemporary knowledge permits. It is illuminating to observe how quickly the general public has learned to find its way to university clinics in the belief that the latest information on the cure of diseases is to be found there, where the search for their causes and nature is actively going on. The fear, once entertained, that patients dread examinations by students and are unwilling to subject themselves to novel procedures even though undertaken with proper precautions has been found not to exist or to have been much exaggerated. How to carry on clinical research is one of the lessons which has been learned.

Now, what can be successfully undertaken in the way of research in clinics depends on several factors. It is obvious that the subjects for research are diseases which the patients in a clinic present—these being presumably representative of the forms of illness present in a community. Certain illnesses can be profitably studied—others not. It would for example have been futile for Borelli or for von Helmont in the 17th and 18th centuries to study infectious diseases. Underlying and contributory knowledge was not yet available.

In the choice of subjects, what I have been calling the level of organization counts—and counts heavily. A distinguished biologist of the past generation spoke often to his friends of the uselessness of investigating diseases until more

was known about the behavior of cells, the ultimate proximate constituents composing animals and plants. In certain directions his view was undoubtedly sound. But sera, like those used successfully in treating certain pneumonias or in diphtheria; or a drug like quinidine; or bacteria as causes of diseases; or fibrillation of the auricles as underlying a striking disorder of the heart beat—all these can be, have been, and are being studied to the great benefit of man without carrying on the investigation at a level of organization much below that on which the going concern which is the organism, carries on. It goes without saying that every analysis occurs on a level simpler than that of the thing analyzed. That is in the inescapable nature of analysis. But how far below? I have been saying, not very far, because relevant knowledge is usually not available—and in the solution of a problem, a level too far below may cease to be relevant. In analyzing morbid processes, the opportunity should be available to carry on an investigation at that level precisely, where an experienced or an especially gifted person decides it may be profitable.

Objection is raised on occasion to affording this opportunity in clinics, the point being that that opportunity should be sought elsewhere either because elsewhere the cost, financially, may be less; or because the inclusion elsewhere of that research may be more appropriate; or because historically there is value in retaining that study at the locus of its origin. But this is a workaday world; it is difficult to get things done anywhere; men carry on, each his own business and do that with difficulty and against odds. Answers are sought because they are needed. Pathological anatomists, for example, are often in despair because of the lacunae, of great importance to them, left by anatomists. The situation is exactly similar when clinicians require information not supplied by physiologists. But even if anatomists and physiologists have developed a subject, there can be no obligation upon them to go on with it. They may not be aware of the need of a next step. To those to whom taking it is necessary, it is scant comfort to know where preliminary investigations were carried on, if they are no longer being housed there. The fructification of ideas can not be shackled to a building or even to a locality. But even if the study of a subject is duplicated, the loss is usually not great. Identity in result is rare, mutual criticism is profitable, slight differences in procedure are desirable.

There must of course be some sort of common sense on what is investigated in clinics; no one now would regard it as sensible to establish a laboratory for the study of electrons. But such researches as on the metabolism of bacteria, on nomograms describing acid-base and other equilibria, the location and behavior of salts and water, the mechanism of respiratory ferments and no doubt a host of others seem to be appropriate. To afford hospitality in clinics for such studies seems wholly reasonable. So will domiciling other activities, when the principles involved are scrutinized and understood, such as describing long drawn out diseases and senescent states, especially when the interest in them is peculiar to the clinic, and the emphasis necessarily different from that outside.

The question finally arises as to whether men exist in clinics willing to devote themselves to investigations at fundamental levels. Though enterprises at such levels are relatively new, it appears already that little or no difficulty is being experienced. If there is difficulty it exists perhaps in the temptation to draw to too practical purposes, the labors of those who should be studying at simpler levels. But if so-called fundamental researches are fostered, there exists the possibility of guiding them within pragmatic limits, and of acquainting clinicians with the value of such enterprises. Against the cost, if the cost

is high, must be balanced the motives, the interest in, the concern for the subject. It seems too theoretical to expel from clinics what can be done there profitably, especially when a clinical interest meets with no outside echo. There are things, it seems, more expensive than money.

The discussion on the nature of the medical clinic has not, I believe, these many years past, given due place to these more general aspects of its life. Primary attention was focussed on practice and on teaching because they seemed to be more urgent. These three, teaching, practice and research can, of course, be conducted as coordinate functions. The devotion to practice and to teaching must in no sense be whittled away. But it will not be, if the experience of recent years is a guide. What is wanted is a realization that in university clinics, all scholars need not be cut according to the same pattern. Traditionally the roles of teacher and practitioner have been emphasized—perhaps overemphasized. But a clinic affords opportunity for the display of diverse talents; there can be doubt no longer that men of diverse talents can find happiness and opportunity there. To arrive at the precise specifications should not, within this framework, be too difficult. If the conviction begins to prevail that these various functions should find their home there, their adjustment and accommodation may safely be left to the slow, one would hope not too slow, processes of time.

The crucial point appears to be that, to succeed, research in medicine must be regarded a serious undertaking. For whatever reasons, the issues are now regarded as sufficiently urgent by the general public, so that government is devoting increasing attention to the health of the community. To take this problem seriously means that scholars in medicine must be permitted to be serious, as are those in other callings. Education and the equipment for research must of course be adequate. And the rewards for service must be ample. Free and frequent criticism must be cultivated. This has been sharp in a technological sense. Experimental nonsense is not lightly tolerated. From a more general point of view—that dealing with the purposes and direction of research, criticism seems to be less well informed. Criticism of a kind can be found in presidential addresses, but the vigor, insight and fearlessness displayed is perhaps not sufficently incisive.

This is what I understand the meaning of medical research to be. The study of diseases has been separated in a category somewhat different from that of the other sciences. That has been due in part to the nature of its subject matter, being in a limited sense, less enduring than that taken for analysis in the other sciences. It has been due in part also to the lateness with which analytical methods have been employed in the study of diseases. The use of them now is in full swing but, being new, the education of men eager to employ them has not been adequately conceived to this end. For this reason also, a critical approach to the analysis of diseases has not yet fully evolved.

Of the objects of human interest, diseases are far from the least. The need for getting on with the understanding of many maladies is urgent. These are very varied, and require for their elucidation professional insight and equipment of a high order. The problems are becoming not less, but more intricate, the more the methods of empiricism change from crude to less crude. The meaning of medical research is to understand the mechanisms at play and to be concerned with their alleviation and cure.

THE ENTOMOLOGIST AND HUMAN HEALTH

By S. MARCOVITCH

TENNESSEE AGRICULTURAL EXPERIMENT STATION

IN the gay nineties the entomologist was pictured as a spectacled professor happily chasing butterflies with a huge net, quite oblivious to his surroundings. If some one with shrubbery or garden cared enough to consult him, this old gentleman could tell a story of the relation of that butterfly to the injury caused by worms on the plants. He was happy to think that the hours of ecstasy spent with his insects was not all selfish delight; and he was still happier if he could devise a remedy to save the potato crop from being completely chewed up by the potato bug, or free his cattle from the dreaded Texas fever tick.

In the last twenty-five years our insect foes have increased so enormously that a conservative estimate places the damage to our health, our crops and our houses, caused by insects in the United States, at not less than $2,200,000 a year. To stay the enemy, over 100,000,000 pounds of insecticides are now used annually, under the direction of entomologists. From an obscure bug chaser, the entomologist suddenly emerges as the most powerful dispenser of lethal poisons the world has known, making the work of the Chemical Warfare Service puny by comparison.

Just as suddenly, Messrs. Kallet and Schlink discovered that all fruits and vegetables are dosed with arsenic and lead and that thousands are dying because of government indifference. Because of failure to enforce the pure food laws, they consider the real rascals to be the Food and Drug officials. Since the numerous poisonings are not played up in the press, Mr. Schlink, with the zeal of a crusader, proceeds to tell us fearlessly that even their own words understate the true situation. "Six persons poisoned in California in 1931 by greens sprayed with lead arsenate. . . . A four-year-old Philadelphia girl dead in August, 1932, from eating sprayed fruit."

Now Mr. Schlink, being a trained engineer, does not ask that you take his word for it. Scientifically, he refers you to "the most thoroughgoing of recent investigations of arsenic poisoning" made by Dr. C. N. Meyers and Dr. Throne, of the New York Skin and Cancer Hospital. Their investigations have shown that arsenic was the factor causing "bald spots" and the increasing amount of baldness. Speaking of the high arsenic content of fish, Meyers reported in *Industrial and Engineering Chemistry* as follows: "It is well known that certain individuals are unable to eat fish, and that others can not eat certain varieties of fish. An examination of representative fish has shown that arsenic and lead are present in certain parts of these specimens. The values found show the relation of the use of insecticides for the purpose of destroying larvae: Man destroys the larvae; the fish eat the larvae; and man eats the fish." Meyers is also concerned for our birds, which are destroyed as a result of eating insects associated with the destruction of fruits and vegetables. In answer to this contention, F. E. Whitehead, of the Oklahoma Agricultural Experiment Station, has shown experimentally that there is no danger of humans being poisoned from eating chickens that have eaten poisoned grasshoppers.

Again, according to Schlink, "Farm animals are frequently poisoned by browsing under the orchard trees, or licking their branches. The meat and milk from affected farm animals is of course poisoned." With this as a clew, the prevailing and perplexing stomach

upsets seem to be easily explained and robbed of their mysterious origin. The exact cause of the intestinal disorders from which Barbara Stanwyck, Jean Parker and Margaret Lindsay suffered is now thought to be poison sprays used on vegetables. The pictures of the famous screen actresses appeared in the newspapers and started a wide-spread inspection of fruits and vegetables at markets. In the absence of known causes, such gastrointestinal symptoms, in the opinion of medical experts, arouse suspicion of lead and arsenic. On the other hand, H. C. Sherman states that defective sanitation of food due to bacteria may result in serious cases of poisoning. "Sanitation is the means of prevention of all such impairments of health by food."

Dr. Hanzlik, of Stanford University School of Medicine, analyzed cabbage sprayed with lead arsenate and found .02 to .45 grain of arsenic per pound, and concludes that "one or two grains of arsenic may be toxic or fatal to an adult." As long as Dr. Hanzlik and others confine themselves to the *chronic* effects of arsenic and lead on fruits, they are safe, for no one has the evidence to refute them; but when reference is made to fatal doses, they are confusing the issue, for the strengths of fatal doses are well known. Text-books on pharmacology are not interested in lead arsenate but in Fowler's solution used as a tonic. A fatal dose of arsenic trioxide dissolved as Fowler's solution is 5 milligrams per kilogram of body weight. The relatively insoluble lead arsenate, however, has a toxicity of 500 milligrams per kilogram of body weight. In other words, white arsenic is 100 times as toxic as lead arsenate. To be scientific, we must designate the compound we are dealing with. The same error is made by Mr. Schlink, from whom we quote as follows: "The decision of the Food and Drug Administration to permit permanently a residue of 1/100 of a grain of arsenic trioxide in each pound of fruit. . . ." Here again arsenic trioxide is confused with lead arsenate. A poison to be most effective must be soluble. The well-known and insoluble barium sulphate swallowed in x-ray studies is non-toxic, while the same material as soluble barium chloride would be fatal. The famous Manchester outbreak of arsenical poisoning in beer was also caused by white arsenic in solution and not by lead arsenate.

We will leave the determination of the effects of arsenic and lead on fruits to the U. S. Public Health Service, which is now engaged in its study. Meanwhile, arsenical substitutes containing fluorine have been developed, such as cryolite. In 1932 this insecticide appeared to be the ideal material; then a report appeared from Arizona showing that mottled enamel of the teeth was caused in that state by fluorine dissolved in the water supplies when obtained from wells. The Food and Drug officials immediately imposed a tolerance on fluorine of .01 of a grain per pound of fruit, or 1.4 parts per million. Since the scope of knowledge was restricted, they believed that fluorine could not be more toxic than arsenic. Once again a chemical in solution was confused with a relatively insoluble material, such as cryolite.

For the past two years the Tennessee Agricultural Experiment Station has been engaged in a study of the toxicity of fluorine as it occurs in drinking water, with the toxicity of cryolite ingested in the quantities involved in the spray-residue problem. The details of this report are available in bulletin form, and only a few of the most significant findings will be mentioned here. When fluorine occurs in the water supply, more fluorine may be swallowed through the process of cooking than through drinking. Water is consumed in greater quantities than all other substances ingested, especially during the summer months. Assuming that 10 per cent. of our fruits and vegetables

are sprayed, the consumption of water is 30 times as great as that of sprayed food. Teakettle scale from a mottled-enamel area was found to contain 8,072 parts per million of fluorine.

Marine foods such as salmon, sardines, and baby foods prepared with bone meal (endorsed by the American Medical Association) contain up to 12 parts per million of fluorine; yet mottled enamel has been produced by no other means in the United States than the continued ingestion of water containing toxic amounts of dissolved fluorides during the period of calcification (between birth and eight years of age) of the crowns of the permanent teeth. The situation is aptly stated by Dean, of the Public Health Service, as follows: "In the light of present knowledge mottled enamel is a waterborne disease associated with the ingestion of toxic amounts of fluoride present in the water used for drinking and cooking during the period of tooth calcification." The present tolerance on fluorine is, therefore, a standard for water supplies and has little or no relation to our spray-residue situation.

Another important advantage of cryolite is that it is incapable of causing fatalities, regardless of the dose consumed, and that it is a much safer material than lead arsenate, being less than one per cent. as toxic to human beings.

In order that a broad view of the situation may be had, the problem of the insect menace deserves consideration. Few people not directly concerned realize the constant and relentless warfare that the agriculturist must wage against hordes of injurious insects in order to arrest their remarkable productivity. The apple is said to have as many as 500 species of insect enemies. Long before the fragrant pink apple blossoms make their appearance, a battle has been waged against the San Jose scale by means of oil sprays. With the resumption of growth in the spring, the tree is beset by lice, caterpillars, weevils, worms, bugs, and numerous other pests. To aid him in his efforts to preserve our food supply, the farmer looks to the entomologist. If the orchardist offers wormy apples for sale, he is practicing adulteration by adding a material to the apple. Whether or not an added material in minute quantities is deleterious to health is difficult to prove legally. And so it seems that in a society whose economic and social forces are delicately poised, we must choose between a small, malformed apple, inhabited and adulterated by worms, and a large, well-colored, appetizing apple, which contains minute traces of material added for its preservation. In the final analysis, we have no choice in the matter. We must protect the fruit and the vegetable if we would preserve our own bodies. We must fight off the insect menace which threatens to take possession of our food supplies.

ON FOOT THROUGH TANGANYIKA

By MARIUS FORTIE

MILANO, ITALY

I

On Tuesday, June 6, 1933, I started from Arusha, a small town near Mount Meru in the Kilimanjaro Massif, three degrees south of the equator, in Tanganyika Territory, East Africa, with a safari of twenty-one porters, one guide and three servants—all natives. The word safari means a journey on foot and with porters. It also indicates the travelers themselves and the loads. The main purpose of my safari was to trace African and Asiatic friends not seen or heard from since 1906, when I had left the land after a sojourn of five years, during which I had gone almost African, living close to the natives, loving them and speaking their language with youthful spirit and relish. I had gone back in 1907, and again in 1917, spending altogether more than twelve years among the Bantu, and incurring natural obligations which belated conscience pangs bade me discharge in 1933. I also purposed to observe changes in native life, and the spread of the Swahili language during the last thirty years.

With the exception of the provinces of Ruanda and Urundi, mandated to Belgium, Tanganyika Territory covers all pre-war German East Africa and is administered by Great Britain under mandate from the League of Nations. It is a strictly tropical country unfit for white settlement, bounded by the Indian Ocean, Kenya Colony and, roughly, by the three great fresh-water lakes, Nyanza, Tanganyika and Nyasa. It has an area nearly five times that of Great Britain; a native population of more than 5,000,000; about 10,000 whites and 30,000 Asiatics, mostly Arabs and Hindus from British India.

The natives are nearly all Bantu Negroes on a fairly uniform level of culture, speaking a variety of vernaculars dominated by Swahili, the great Bantu-Arabic *lingua franca* of equatorial Africa, used and understood by fifty million Africans, and said to gain one million a year. Although Tanganyika has some towns, the vast majority of the natives are small peasant farmers and cattlemen living in bush villages practically as they did a thousand years ago when the Arabs began to reach the Zanzibar coast and to penetrate the interior with their reckless safaris.

Tanganyika has a few railroads, and a system of so-called motor roads seldom passable in the rainy season. My objectives compelled me to travel on foot by the old-fashioned safari which must keep close to water and rations. Hence, usually I followed the native trails which lead from hut to hut, from village to village, and are kinder and cooler than the government roads to bare feet. My two safaris of 1933 and 1934 covered more than 3,600 miles, averaging thirteen miles a day, but marching frequently as much as thirty miles between camps. My aim was to go over the route of the safaris of my youth, and to revisit about two hundred bush villages in the vast area between the Great Lakes.

With plenty of time available, and the dry season just beginning, I was not tied to a particular itinerary, but followed a generally westerly trend toward Tabora. The Masai still hold much of the country between Arusha and Mbulu. A few are taking to agriculture, but the

TWO OF THE AUTHOR'S PORTERS

bulk graze their cattle as of yore on the slopes, in the bowls and basins of a mountainous district to heights exceeding nine thousand feet above sea level. Milk was plentiful and there was no lack of game for meat, but my porters often went without their rations of corn and millet meal. Water was scarce and bad. There were no fruits or vegetables, and it was too early in the year for the wild fruits of the bush. As almost everywhere else in Tanganyika, I found growing near habitations a sort of dandelion (*Sonchus bipontini?*) called by the natives *mchunga* or *msunga* because of its bitter taste. Mixed with the likewise common purslane, it made a tasty and wholesome green salad.

I crossed the alkali desert of Engaruka on the night of June 11–12, and rested for two days at the oasis of the same name, a Bantu settlement established by the Germans as a model agricultural village and police outpost in Masailand. There seemed to be much sickness among the people, and a physician from Goa made a good living. Here, as elsewhere in the colony, the natives flocked to my tent to be doctored for common ailments, skin, eye and lung diseases, and nowhere did I find them in possession of really valuable remedies. Sensational statements have been made, great hopes have been aroused regarding plants of wonderful medicinal value in Tanganyika. I saw no foundation for such statements or hopes.

On the way to Ngorongoro Crater, one of the great shows on our planet, we had to surmount steep stony trails over high mountains with chilly fogs in the morning and freezing temperature at night. On June 19, at an elevation approaching 9,000 feet, the tent fly froze stiff and could not be folded till four hours after sunrise. That same day we had an almost sudden drop of three thousand feet into the crater, which swarmed with zebras, gnus, kongoni and other species of antelopes. Ngorongoro Crater is a game preserve with high fees for limited hunting licenses.

Climbing out of the crater through dense rain forest, I took the trail to Mbulu through a region of typical savanna, where systematical deforestation was carried out by the government in an effort to check the tsetse fly, which spreads sleeping sickness among humans and animals. All efforts, however, are merely experimental. There was no evidence that the work done had any effect on the incidence of the calamitous fly, whereas it was evident that the insect liked to travel by train, automobile and airplane, and was thus carried rapidly to areas where it had never occurred before.

WOMEN OF BUSH VILLAGE SELLING YAMS

EAST AFRICAN HINDUS

PITCHING CAMP AMID MILLET FIELDS

Six marches from Mbulu the country began to flatten out into plains dotted with the granite formations met all the way to Tabora right into Lake Victoria at Mwanza. The light forest abounded in plants yielding edible fruits, nuts, berries and tubers. The *mfuu* (*Vitex cuneata*) was common and welcome to all. It is a handsome tree producing black fruits ranging in size from an olive to a walnut. The pulp is mealy and sweet, the stone woody. Days later we found near Tabora a clump of trees bearing fruits as large as plums, but not as palatable as the smaller variety.

I planned to reach Tabora cutting through a depression of the Vembere Steppe crossed more than once in my youth, but upon reaching Ushora, a village of rustling doom palms forty miles out of Singida, I heard that several natives had disappeared in bottomless ooze while following the trail I had in mind. So the safari made a detour to the right. We crossed the northern tip of the steppe, floundering through a mile of black mire, then were chased by tsetse flies over many miles of elephant grass, thorny mimosa and waterless light forest without settlements. On July 19, we had to camp in the bush without water.

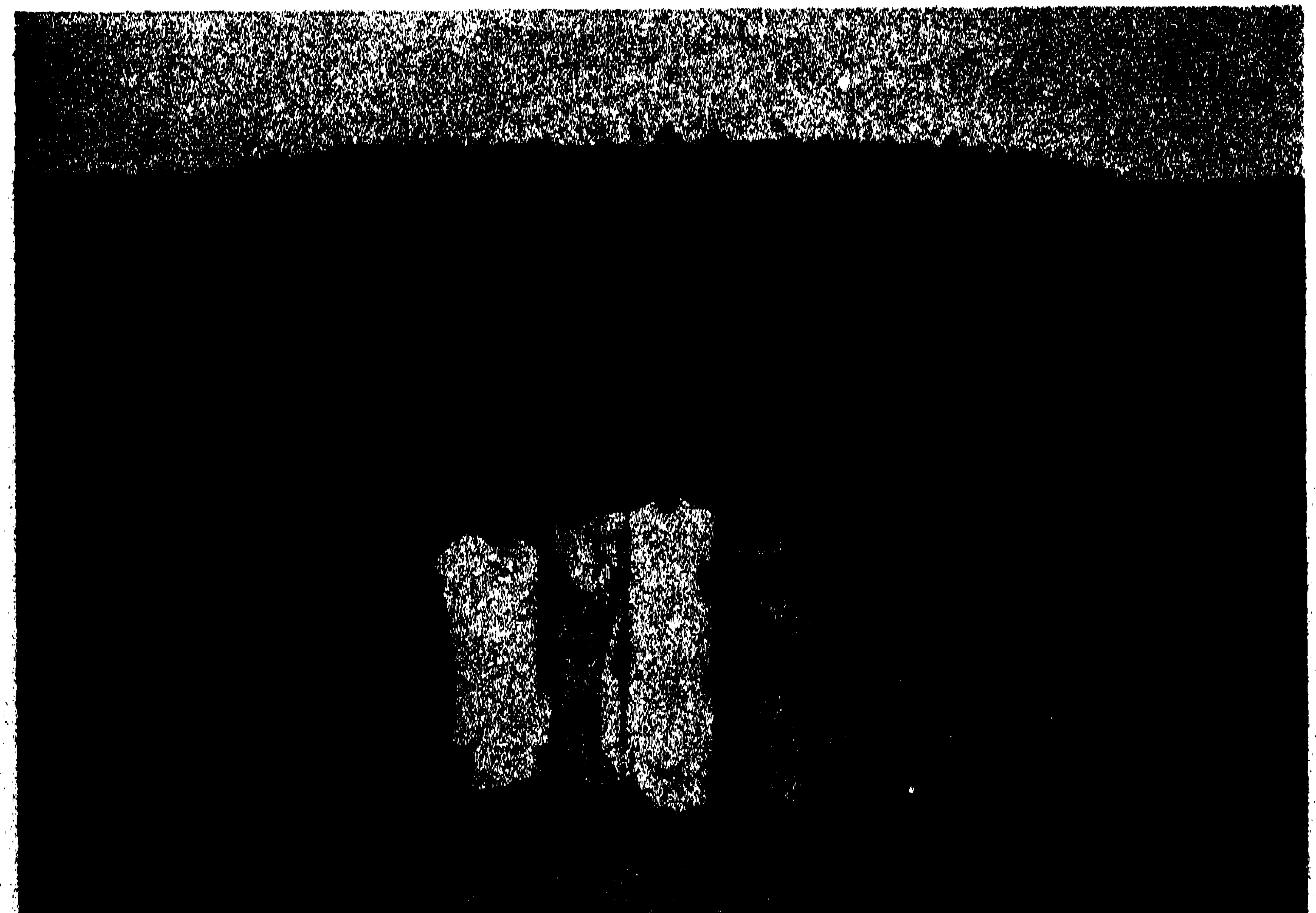
There occurs frequently in that region a tree which I have not been able to identify, called *mbungu* by the natives of Unyamwezi. It sends out long roots, horizontally, like pipes, less than two feet from the surface. A four-inch root will run several feet without tapering, then branch off with two slightly smaller roots which will likewise run many feet without a taper, branch off into smaller roots, and so on. The roots are flexible, like lead. A six-foot length of four-inch root, held perpendicular, will drip almost a pint of cool water, clear and wholesome. My porters found

several *mbungu* trees, also two vines, arm-thick, that yielded wholesome water.

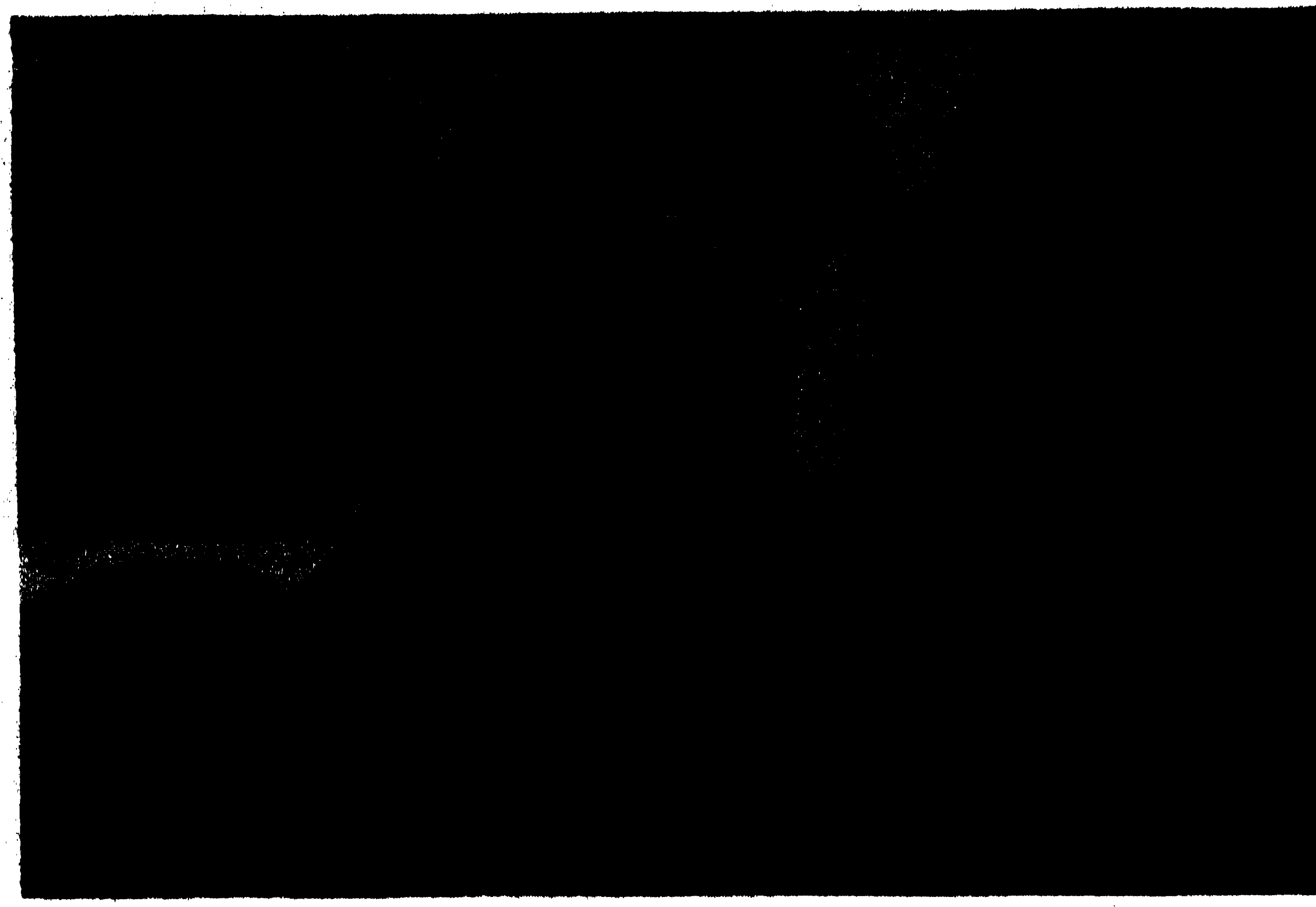
The light forest abounded with trees bearing edible fruits, some of which seemed to me of great promise if cultivated and improved. Although I found it harsh, my men ate freely of a beautiful apple-like fruit called *mgongo* (*Sclerocarya caffra?*), also many varieties of *Strychnos*, some of which I relished. I saw many small trees of the wild custard apple (*Anona senegalensis*), all bearing delicious fruit. The tree resists bush fires and, if improved, might easily become as valuable to native and colonist as the apple in the West.

Emerging from the waterless bush, we entered a settled region with extensive fields of corn, millet, yam, cassava, peanuts. Although water seemed scarce, the landscape had a green and prosperous look. Normally the rainfall is sufficient for agricultural and pastoral purposes nearly everywhere in Tanganyika, but the natives have yet to be taught the rudiments of irrigation and water conservancy. It is lack of water for domestic purposes that prevents native settlement of large areas, of which the government has deprived the native under pretext that he makes no use of them. Many such areas, declared crown lands, have been given, leased or sold to immigrants, white and Asiatic, for pastures and plantations, and costly mistakes have been made in cattle, rubber, cotton, sisal, tea, coffee.

On the morning of July 25, we halted under the imposing fortress which the Germans built in the '90s on a hill commanding the famous Arab-Swahili town of Tabora. It is now overwhelmingly Hindu, as is the important port of Mwanza on Lake Victoria, reached on



A MUHIMA CHIEF OF RUANDA



FRENCH FATHERS AT KAREMA

August 14, over the level, thrifty land of Usukuma inhabited by one of the finest and most progressive Bantu groups in Tanganyika. Gold, both alluvial and reef, coal, tin, diamonds and other minerals have been located in this district, also in widely scattered areas elsewhere in the colony. It seems that the entire granite-ribbed plateau within the three Great Lakes must be considered highly mineralized. The gold fields of Musoma on Lake Victoria, those of Sekenke and Singida, and especially those of the Lupa basin near Lake Rukwa, have already taken a prominent place in the economy of the land, with growing disastrous effects on native life.

In the meantime, after an absence of thirty years, I found no advance in the economy of the bush villages. Under compulsion, under the pressure of taxation in cash, the natives raise with varying success cash crops such as peanuts, cotton, coffee, tobacco. But not a single food crop, not a fruit, not a vegetable, not a domestic animal has been added to the village economy. Year in and year out, the natives of many districts eat for months on end only a mush of millet or corn meal, with relishes of boiled weeds, grasshoppers or termites. Meat and fish are rare treats, legumes are scarce and soon weeviled, and there is a general lack of fats in the diet because, as a rule, the entire peanut crop must be sold to the Hindus to provide tax money.

I remained a week in Mwanza to reorganize the safari and plan the next lap to Ruanda and Lake Kivu. After turning the Emin Pasha Gulf, we entered a region, extending through Ruanda into Uganda, where plantains and kidney beans are the staff of life. The green plantains are peeled with a bamboo knife and steamed in earthen pots with fresh banana leaves and little water. The beans are cooked separately and require hours of boiling. Salt is added liberally to the plantains during the cooking. When done, the whole is dished out on

green leaves, and I found it nourishing and palatable fare. The beans are considered a relish, and so are grasshoppers, termites, certain tree caterpillars and mosquito-like gnats, a pest on the Victoria Nyanza. They neither bite nor sting, but drift with the monsoon in dense banks, often smothering fishermen to death in their canoes. At night the gnats are collected in great quantities near lights and fires, and are pounded into hard loaves and cakes as nutritious and lasting as pemmican, but not nearly so palatable to a white man.

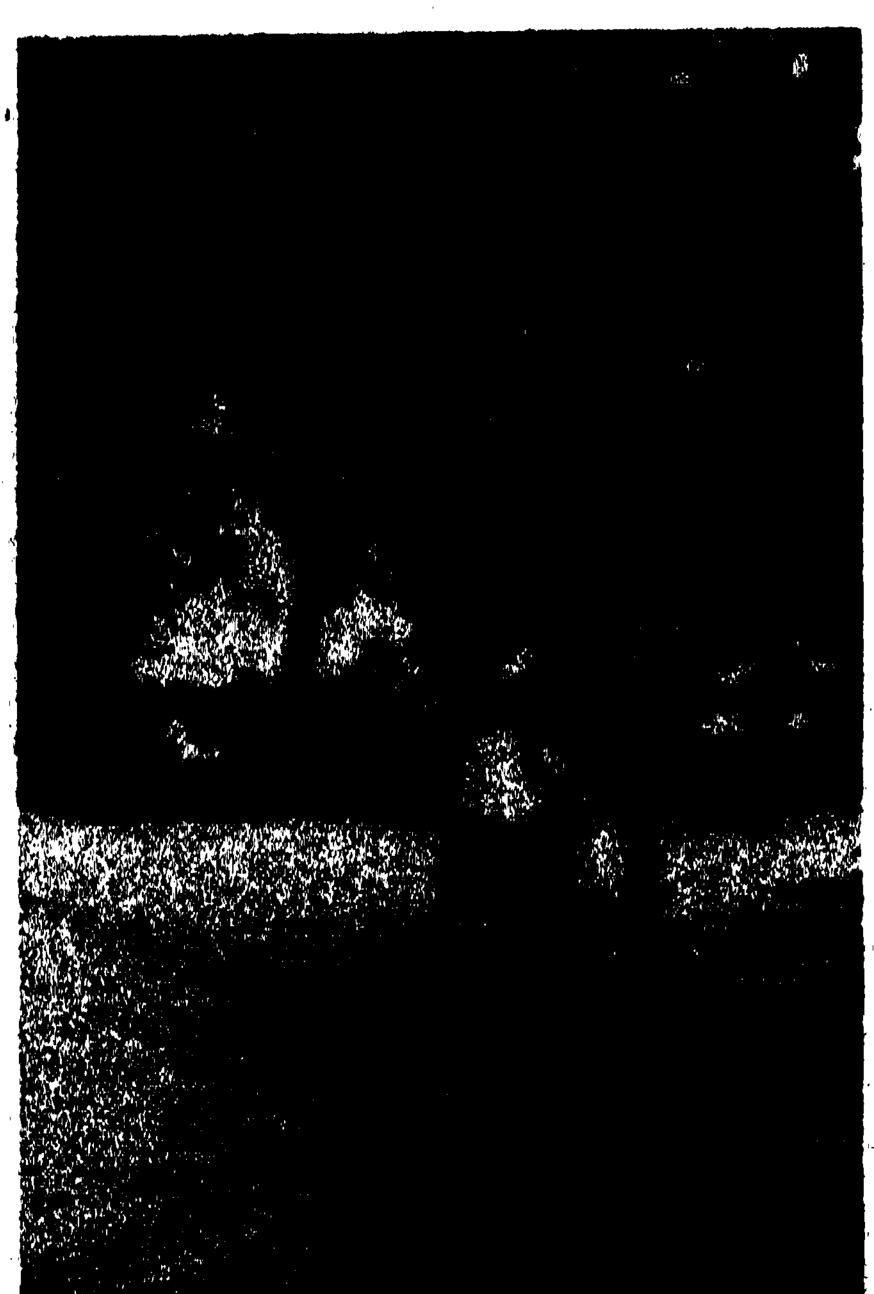
Our trails were strewn with the hard shells of edible *Strychnos* and with the stones of the *mbula*, a fruit of which we ate a great deal. It is borne by several species of *Parinum* (*P. curatellefolium, P. excelsum, P. macrophyllum*), large handsome trees with pinkish blossoms, yielding a close-grained wood of light color, fine for cabinet work. The fruit, in size from a plum to a goose egg, has yellow meat, mealy, sweet, nourishing. The woody stone contains seeds of fine flavor, raw or roasted. I often saw before the huts mounds of cracked *Parinum* stones, but never a tree that looked as though it had been intentionally planted. Yet this beautiful and valuable tree is common in the bush. I saw it growing, but bearing harsh fruit, to considerable elevations in the Livingstone Mountains. Selection and domestication would surely make it one of the most useful trees in East Africa.

On September 11, five marches west of Biharamulo, I pitched my ninety-eighth camp on a bluff overlooking the junction of the Ruvuvu and Kagera rivers, within hearing of the Rusumu Falls, down which tumbled a great volume of water. We ferried in leaky canoes into Ruanda, now under Belgian mandate, where, owing to the lack of an $8 consular visa, I was compelled to give up the march to Lake Kivu and to reenter Tanganyika

A WITCH DANCE

for a safari of twenty-five days to Ujiji. We tramped over Keza, Kibondo and Kasulu through one of the worst sleeping-sickness belts in Africa. There the government carried out on a large scale what, in the present state of knowledge, seems an effective remedy: it was moving 18,000 native families to new land. I saw everywhere abandoned villages, fallow fields, lines of natives straggling to new settlements or concentration camps, where the Franco-Algerian White Fathers are a great help in a great need.

From Kasulu, a picturesque fortress of German days, we dropped in forty-five miles from a high of 6,000 to a low of 2,560 feet, the present level of Lake Tanganyika, entering the rolling lake region of sandy loam with great fields of cassava and, almost suddenly, the trees beloved of the coast Swahili: papaya, mango, date, coco and oil palm. Although still a large settlement, Ujiji is now less important than Kigoma, a new town at the terminal of the Central Railway. Here my porters found in overabundance the delights for which they had yearned through fifty hard marches since leaving Mwanza, and the safari went to pieces. With difficulty I managed to keep a nucleus of ten men and to place them on board the steamer *Liemba*, which sailed south the night of October 16. Three days afterward we landed at Kipili, below the old French mission of Karema, and, with additional porters furnished by the government, began the march to Kasanga and Abercorn through Ufipa.



THE AUTHOR'S KITCHEN DEVIL AT TUKUYU

Ufipa presented a Bantu culture older, more developed, more resistant to change, hence considered more backward by impatient and unsympathetic observers. Instead of the isolated huts and small villages common in the Tanganyika bush, here were towns of several streets lined with rectangular thatched dwellings built substantially of logs, plastered with clay, often whitewashed. The streets swarmed with children unclad, unwashed—the poor hop-a-back babies grimy bundles smothered with flies. Because of the tsetse, goats and sheep are the only live stock, though there is a plenty of chickens and dogs. The fields and gardens were in distant valleys or river bottoms, and I saw old granaries, or silos, of hard termite clay scattered through the wilderness.

That told me why the Tanganyika Bantu still exhibits behaviors greatly at variance with changed conditions: the conditions have changed recently, the behaviors are rooted in a past reaching back thousands of years. Until thirty years ago, Ufipa was exposed to the raids of the predatory Wangoni and Matabele. The Matabele chief Uzwangendaba is buried at Chapota, near Kasanga. So the Wafipa built their villages five, ten miles from the fields, hid their stores of food in the wilderness, and when the raiders came gave up their dwellings and

WASOKIRE NATIVES OF TUKUYU

fled to the bush. An African village of sticks, mud and straw is easily rebuilt if the population can save its provisions.

That told me likewise why the Tanganyika Bantu is interested only in his few standard crops; why he plants no fruit trees, or trees of any kind. In the past his village has been constantly on the move for two main reasons. In the first place he did not practice crop rotation. He tilled an area to exhaustion, then brought a piece of virgin land under the hoe, moving his village to remain reasonably near his fields. In the second place, warfare, raids, feuds often drove thousands from their homes overnight and forever. Villages might also be abandoned on account of drought, fire, unremitting crop failures, vermin, lions, sickness, witchcraft. As a result, which persists as a racial trait down into the present time of relative stability and security, the native will not undertake works of a far-flung or permanent character that may interfere with a sudden move, or make it too bitter, too regrettable. He plants no trees, digs no permanent wells, builds no substantial dwellings or shrines. It is only when faced by necessity that a native community will undertake extensive jobs of irrigation against drought or of fencing against pigs and other vermin. Thus when the family, the clan, the tribe or the nation moves, nothing lasting is left behind, and in a few years almost all traces of human occupation disappear.

I found Ufipa in the grip of a disastrous locust invasion. Almost the only food available at some camps were heaps of the unsavory insects dried and sauté. The usual fare of the people is a gritty mush of *Eleusine coracana* eaten with a relish of mushrooms, boiled beans, termites or grasshoppers. Game is rather scarce and the live stock seldom slaughtered for food. Vying with children and baboons, I eked out my provisions with the fruits of several species of *Strychnos* trees common in Ufipa.

After leaving Kasanga, the Bismarckburg of German days, a camp was pitched on the brink of the Kalambo Falls, said to be the highest in Africa. There is a single sheer drop of more than 700 feet, twice the height of the Victoria Falls, and more than four times that of Niagara Falls. From Abercorn we struck across Northern Rhodesia toward Karonga, on Lake Nyasa, touching Isoka, the Fife of some maps. Disease and homesickness had reduced to seven the experienced porters of the old gang, and I had to recruit from village to village local men who gave no end of trouble. The three hundred miles to Karonga, covered in sixteen days, were exceedingly hard. The long marches were made more difficult by the bush fires that burned every blade of grass and singed every tree from river bottoms to mountain peaks.

On reaching Karonga on Lake Nyasa nearly every porter deserted, and so did my cook. A small steamboat took me to Mwaya in Tanganyika, where I was able to organize another safari for Tukuyu, the Neu-Langenburg of the Germans, a pleasant place of pines and eucalypti 6,000 feet up in the hills. The rain-clouds were now rolling up from the south, and I saw that my safari must soon come to an end. A reluctant column of local natives carried my loads in four days from Tukuyu to Mbeya through the mists and storms of the chill Igali Pass, reaching Mbeya on December 7, 1933, 185 days and 2,150 miles from Arusha.

Mbeya had become a small town of some importance owing to the Lupa gold fields thirty miles away, which for several years have yielded considerable amounts of alluvial gold. Some reefs were being brought into production, and many optimists predicted the development of another Rand. From fifteen to twenty thousand natives worked all year in the diggings, mainly to earn tax money, with a huge labor turn-over affecting many tribes in Tanganyika, Northern Rhodesia and Nyasaland. Giving way to the demands of the white miners, the government, though pledged under the terms of the mandate to consider the interests of the natives paramount, placed those natives under restrictions of increasing severity, tending to reproduce the appalling conditions existing among the native population in the Union of South Africa.

Great Britain could easily interpret her mandate in Tanganyika in a high and generous spirit of true stewardship. She grants the more progressive tribes—that is to say those that pay taxes readily and buy much Western trash—what is officially styled Indirect Rule, a meager measure of self-government in petty local affairs, provided they be conducted in approved British manner. But the pressure of taxation in cash, the deposition of the native chiefs, the disintegration of Bantu society through missionary propaganda and money economy, cause a growing tendency of the able-bodied male population to leave the tribal villages for town, plantation and mine. Many never return. In a village of 54 huts I found only seventeen able-bodied adult males. The huts were ruinous, the fields neglected, the children untaught and wayward, the women dissatisfied and debauched. In the words of Akeley, the darkest chapters in Bantu history are being written now under the white man's rule.

II

With the big rains approaching, no porters could be found in Mbeya. I was forced to go to Dodoma by truck, then by train to Dar es Salaam, the capital, where I stayed until June awaiting fair weather. On June 21, 1934, I left Dar es Salaam with a safari of twenty-four natives, planning to reach Lake Nyasa and the Livingstone Mountains by way

of Mahenge, Songea and Manda. As the belated rains had continued beyond the normal period, the first three weeks were full of anxiety and hardships for the safari. I had so much trouble with porters sickening and running away, that it was only at Kidodi, nineteen marches from Dar es Salaam, that the safari fell into stride.

A magnificent and appalling wilderness swallowed us up three marches from the coast. Soggy patches of grass ten feet high and ten miles across; mazes of elephant tracks; morasses pitted by the hippos that came up every night from the Ruvu River; gloomy rain-forests where the guides often stuck fast in perplexity, asking counsel of the white man who had hired them for counsel. On July 9, somehow, we emerged at Kidodi on the Kilosa-Mahenge road still deep in mud, still impassable to motor traffic. But it seemed excellent to us and we made good progress toward Mahenge.

In all this region were vast abandoned plantations of Ceara rubber trees (*Manihot glaziovii*), which formed impenetrable jungles where was light forest and savanna thirty years before. On July 14, we reached the large village of Ifakara on the Kilombero River, which it took the safari three hours to cross by wading and canoeing. Excellent rice and fish go from Ifakara to many Tanganyika markets down the Kilombero and Rufiji rivers. I saw here many fine specimens of *Telfairia pedata,* a vine of the cucurbit family called *kweme* in Swahili. It is frequently found associated with the *mvule* (*Chlorophora excelsa*), an immense tree that furnishes beautiful hard wood, termite proof, but liable to dry rot. The *kweme* vine, often more than a foot across, climbs up to a hundred feet and more, the plant spreading over the crown of the tree and producing a profusion of pumpkin-like fruits that weigh up to sixty pounds.

THE NATIVE QUARTER OF DAR ES SALAAM

STARTING A FIRE IN A BUSH CAMP

The bitter, unedible pulp contains from a hundred to three hundred flat seeds two inches and more across. The kernels, roasted, have a rich nutty flavor and yield a sweet oil as good as that of the olive.

Mahenge, 3,400 feet above sea level, was reached on July 17, twenty-seven days and 360 miles out of Dar es Salaam. The next 280 miles to Songea, covered in seventeen days, proved easy and pleasant on the whole, although troubles and difficulties were not lacking. Villages were so few and far apart that I pitched several camps in the bush. In one of those camps a porter dug up a quantity of tubers of a kind he had eaten before, and which I was not able to identify. With some of his mates, he roasted and ate them, and the meal made every one sick. That astonished the digger very much, because he knew his tubers and was quite sure they were edible. He was probably right, but the plant may have been a *Solanum* whose tubers, as happens with Irish potatoes, may occasionally be poisonous.

Fifteen miles south of Songea, reached on August 5, I camped in the grounds of Peramiho Mission, an immense abbey, the mother of many more throughout the region down to Lake Nyasa. Those missions build substantially of brick and stone; they have chapels, hospitals, schools; tailor, carpenter and shoemaker shops; flour and oil mills; forges, brick kilns, great orchards and vegetable gardens, stables with cattle and hogs of good breeds. From Peramiho we entered Umatengo, and during five days we marched through beautiful mountain landscapes reminiscent of the Tyrol. The Wamatengo terrace with their fields the steepest hills to their summits, practice irrigation, and in the villages they bring a brooklet to every dwelling. Among the usual millet and corn were fields of green peas, wheat and Irish potatoes, with patches of coffee in favored spots.

The nights were exceedingly cold in the gorges of Umatengo. At the mission of Litembo, nearly 6,000 feet above sea level, my thermometer fell to fifty degrees immediately after sunset, and hovered around forty all night. Only two days afterward we were on the shores of Lake Nyasa, camped amid huge baobabs, plagued by mosquitoes and heat. We skirted the lake for three days with many detours on account of streams and sheer bluffs, and ferried the Ruhuhu River in two ancient canoes, one of which capsized in a crocodile scare. Manda, big on most maps, had only a dingy post office and two native shops without provisions for me or rations for my men. Thus it was with light loads that the safari began to climb the Livingstone Mountains on August 21.

The level of Lake Nyasa is 1,645 feet. The ten days it took us to reach the government post of Njombe in the Poroto Range were a series of difficult climbs and drops between 8,000 and 5,000 feet, with Njombe at 6,300. It being winter, we met with severe weather everywhere: heavy fogs, chill gales, rain and painfully cold nights. The region had a curious non-African appearance. More than once I was startled by the almost naked Negroes cowering in an icy drizzle around smoky embers before squalid huts, half stable, half dwelling. I would have thought it more natural to find Swiss chalets and yodeling mountaineers.

The only staple food I could get for my porters was a mixture of corn and kidney beans, dried, which were boiled together and so eaten with some wretched relish such as boiled yam tops. There was scarcely any game, the natives did not willingly part with their few chickens, sheep or goats, and the bush offered little to eat on those high levels. Trees of *Parinum* were common, but the fruit was too harsh to eat. In the neighborhood of Njombe I saw the Cape gooseberry (*Physalis edulis*) grow wild in profusion, also many species of *Rubus*, but none in bearing.

After Njombe my porters would have no more rain-swept mountains and polar nights. Hastening through Ubena, a region that had not yet recovered from the barbarous punishment received in the rebellion of 1906 against the Germans, we dropped into Usango, a land of sunshine and plenty. For the first time since leaving the coast, we saw here great herds of cattle, and my camps overflowed with the eatables beloved of the Bantu. One tenth of a shilling bought a gallon of sweet milk and enough millet beer to cripple the safari. The general prosperity found expression in gay cottons and in much drunkenness—the Bantu's only dissipation and solace.

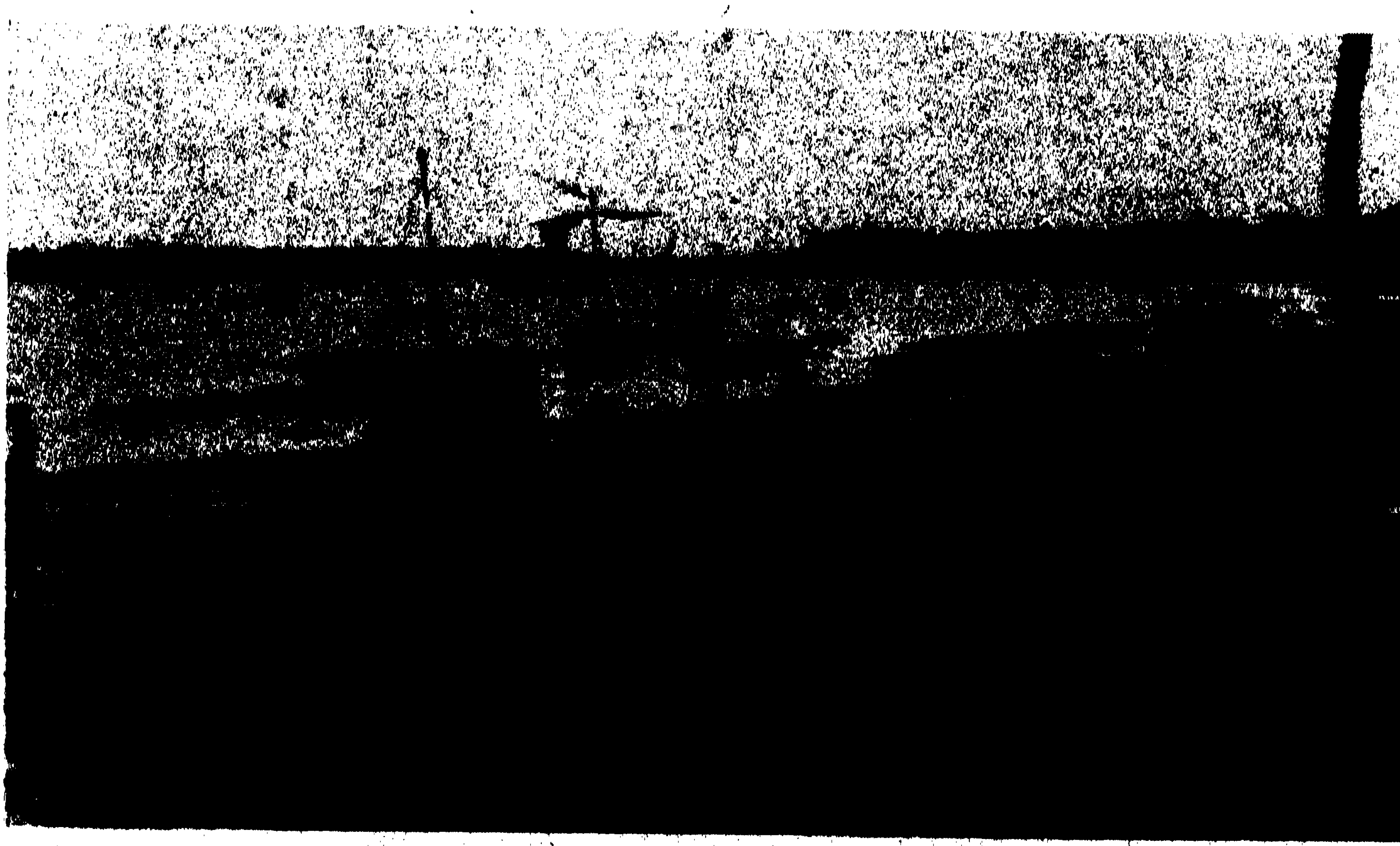
The level plains of Usango ended at the Usafu escarpment, which took us up into the Lupa plateau and the gold fields. At the first camp on the diggings, pitched in a gale on September 12, my safari of twenty men had two bottles of sour milk and a hatful of finger-thick yams for rations, and no water—famine and thirst amid the gold pits, with plenty in Usango a few miles below. But the bush yielded a deal of two unidentified fruits called *sungwi* and *masuka*. Although hardly a food, they whiled away hunger on the march and between naps.

I rested two days in Chunya, a new government mining post, where I was able to give my hungry men corn meal rations in lieu of the daily fifth of a shilling which had been the rule on this safari and on the previous one. Water was so scarce that in many cases watercarriers could make only two trips in twelve hours between wells and mining camps. Hence little mining was done, and that mostly by blowing. The native sifted the alluvial dirt in an iron pan, sorted out the coarse stuff, then blew off the residue until, perchance, a little gold was

A MISSION SCHOOL

left. The best panners were the Wasokire of Tukuyu, canny Bantu who were learning the value of gold much too fast to suit the greed of their white masters. With restrictions and penalties of increasing severity, the government tried to make gold worthless to the blacks and worth more to the whites.

Hurrying toward Lake Rukwa to exchange fresh fish for the now palling game and birds, we followed trails through light forests of leafless straight



CORAL BEACH NEAR DAR ES SALAAM

trees, the ground extensively dug up by prospectors all the way to the Lupa River. Some sluicing was going on at water holes by the river bed, but all signs of prospecting ceased on the right bank. During the next six days, however, we heard the rumble of blasting from the hills on our right. British companies were developing promising gold reefs, a modern mining town was rising at Saza, a few miles above Lake Rukwa, where half a million pounds was being spent.

Our first camp on Lake Rukwa was pitched on September 19. No shooting is permitted within five miles of the shores, but Lake Rukwa is a vague geographical expression in which five miles may mean as little as five inches. Before 1904, the name applied to a body of water about twenty miles long and ten miles across which expanded more than fifty miles to the northwest in one rainy season, and still covers at least three times the area shown on most maps. I found heavy canoes fully two miles from the water, and was assured that the lake would come up and float them in January.

Lake Rukwa is shallow; perhaps nowhere more than twenty feet deep. The turbid water, so charged with soda carbonate as to be hardly drinkable, teems with excellent fish. Catfish attain the size of a man. The shores are mostly flat and marshy, but in places granite bluffs rise sheer from the water and force the traveler to long detours over the hills. Immense flocks of white pelicans and other water birds float in banks offshore or wheel overhead, hippos splash and blow in the reeds, fresh elephant tracks crisscross the trails and dry river beds. Plump hyrax dwell among the boulders and are easily caught near the tamarinds, of whose pods they are fond. There is plenty of bigger game, also of spur geese, ducks, guineas, francolins and large species of pigeons.

But the mosquito and the tsetse fly gave us no peace in that beautiful region —indeed the tsetse chased us relentlessly day and night to the gates of Tabora. Moreover, the Lake Rukwa basin is now suspected of being one of the main breeding grounds of the calamitous grasshopper, the red locust. On September 23, the first day of spring in that latitude, I left Rukwa on the three-hundred-mile lap to Tabora. The safari was held together by eleven porters of the original gang from the coast, and by the fact that I walked every inch of the trail, sharing hardships and dangers. At Kitunda I put the almost mutinous group on a truck that took us to Sikonge, where the march was resumed to end at Tabora four days later, October 7, 1934—108 days and 1,600 miles from Dar es Salaam. After disbanding the safari, I went into camp in the Unyamwezi bush till March, 1935, to avoid returning to America in winter.

III

In the course of this article I have mentioned native wild plants of potential economic importance as foods, which were often a godsend to my porters and to me. Those plants are totally ignored by the immigrants, European and Asian. The government, the missions, the colonists make great efforts to introduce and keep going in Tanganyika plants that, with few exceptions, don't like to grow there. European fruits and vegetables and so-called colonial or tax crops—cotton, sisal, coffee, tea, tobacco—absorb all the attention, none being paid to the numerous plants of economic value native to the land, because their improvement and development would benefit mainly the Negro and bring no quick cash returns to the colonist.

Taxation in cash and other measures compel the Tanganyika native to raise cash crops for export, but the huge abandoned plantations of sisal, rubber,

tea, coffee and cotton prove that the system does the native and the land little permanent good. While shiploads of cotton and cotton seed leave Tanganyika to compete unfairly with the product of more progressive countries, the majority of Tanganyika's five million natives wear only loincloths or skins. While shiploads of peanuts and sesame leave Tanganyika to put the Mediterranean olive growers out of business, the native diet is so lacking in fats that cod and shark liver oils are currently administered in native schools and dispensaries. While the Tanganyika bush is occasionally searched for plants that may do well in Wales, California or Arizona, but usually won't, nobody searches the Tanganyika bush for plants that will do well in Tanganyika itself.

If a botanical expedition went to Tanganyika with the specific aim of studying wild plants of food value for improvement and domestication in Tanganyika, there would be no fear of failure. It would not have to be admitted years afterward, as a noted American botanist admits in a recent letter to me: "There are great thickets of wild fruit trees in Tanganyika, and although I introduced a good many in this country, I believe we have succeeded in establishing only one." It is in Tanganyika in the first place that wild Tanganyika fruit trees should be domesticated and improved to furnish the native more palatable and more nourishing fruit, and more of it, than is now the case with the wild trees, and to teach the native what the West knows of the art. Varieties would almost certainly be developed more apt to do well in America or Europe than the chance-picked wild plants that have failed so far. That can be said of all the fruits I have mentioned; of many more I have eaten and seen eaten by the natives; and of many awaiting discovery and intelligent survey in the bush.

AGING VERSUS INFIRMITY

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BIOLOGICAL change must not be confused with chronological time. We note the former only when its speed is great against a background of the latter as in the growth of childhood, the ravages of disease and the progress of infirmity.

In practice we can distinguish between the program of healthy growth and the progress of disease in childhood because, though both show vigorous change, the type of change is clearly constructive in the one and equally clearly destructive in the other.

Infirmity is not easily noted in childhood because there is nothing unequivocally destructive about it. The child is not ill. He may not be growing as vigorously as his brothers did. He may not be maturing quite so rapidly. Perhaps he is not doing so well at school. His infancy may have been one long struggle to find a dietary suitable to his digestion; his preschool period may have been marked by roughness or dryness of the skin, even by eczema in the folds, by recurrent obstinate "colds," and punctuated by the necessity of removing tonsils and adenoids and correction of visual defects. The grade-school stage may bring out defects of social adjustment at school or home, a high strung nature or a proneness to fatigue with headaches in the afternoon, disinclination for breakfast, stuffy nose in the mornings or an obstinate inability to put on weight. But the doctor pronounces his organs sound; the parents remember that one or both showed the same characteristics in their childhood but, notwithstanding this, they have grown up to be useful and efficient members of society. And so we prate about the infinite variability in human beings and, with fatalistic indifference, delude ourselves that all is really well with the child or, at worst, acknowledge that he is sensitive, subject to nightmares or hay fever, a little delicate, one of Pharaoh's lean cattle, fickle in appetite or averse to active games with other children. We employ a host of rationalizations to hide from ourselves the fact which nature strives to bring home to us that infirmity has its grip upon the child and is handicapping his enjoyment of life.

All physicians are by training pathologists who seek for definite clinical evidence of clear-cut disease and, finding it not, reassure us that this is something the child will outgrow, even as we, his parents, have outgrown similar minor troubles. The man who is forever engaged in treating sickness sooner or later loses sight of health. For him health is the absence of demonstrable disease, not something that sparkles in the eye, glows in the cheek, gives spirit and zest to the day's occupation and radiates through all human relationships. So our standard of health deteriorates and we juggle with abstract theories of what is optimum in growth, vigor, alertness and staying power.

Let me take as an example the life histories of three young guinea pigs from our colony in the nutritional study of the Associated Foundations. Each of these represents the typical progress of its group. One group we deprived of certain nutritionals, namely, vitamins B, E and C, one of B and E but gave a minimum of C, a third of B and E alone.

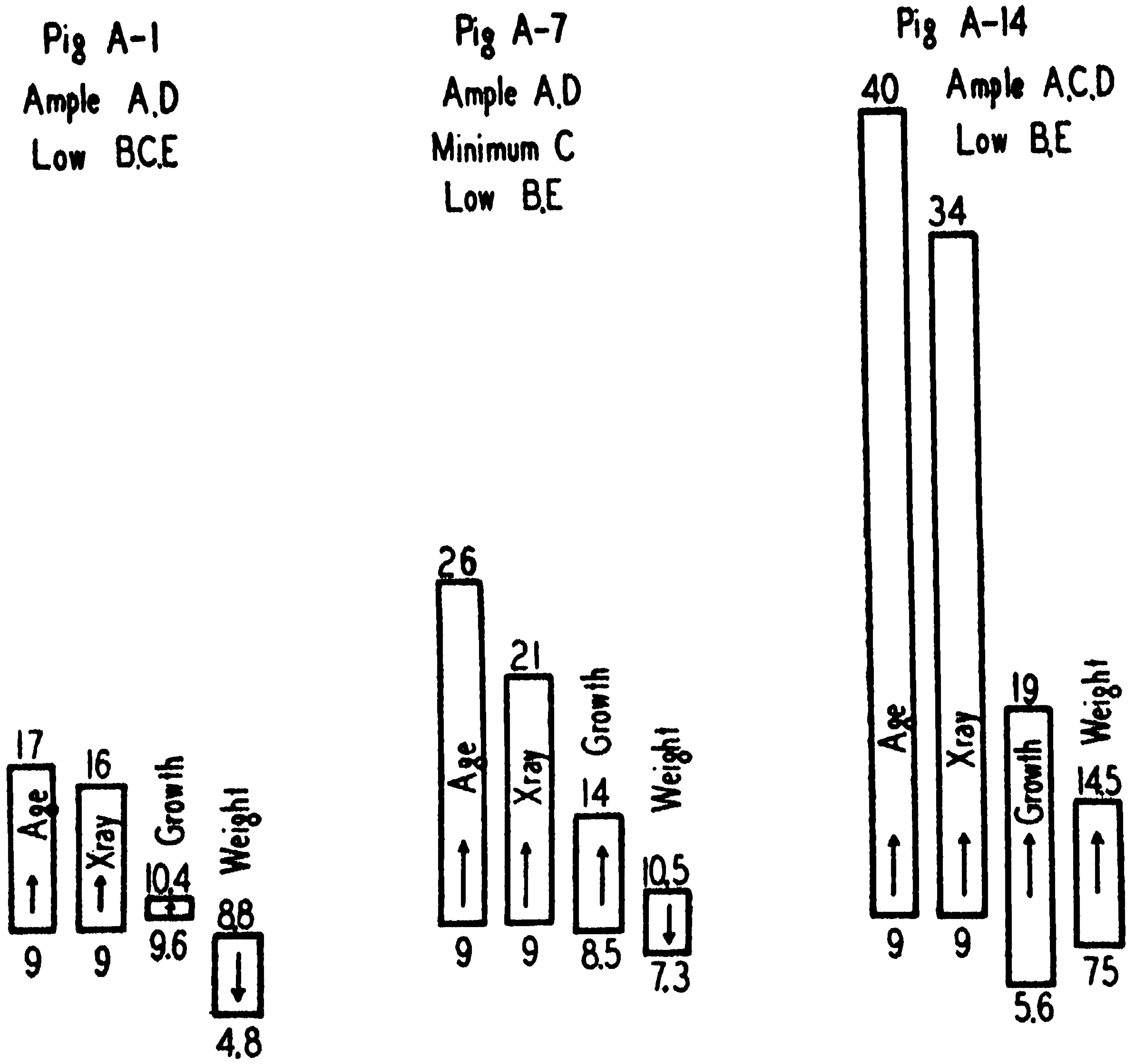

FIG. 1. TYPICAL REGISTERS OF DEVELOPMENTAL PROGRESS. GUINEA PIGS DEPRIVED OF CERTAIN NUTRITIONALS (FROM UNPUBLISHED WORK BY COHEN AND TODD). FOR FULL EXPLANATION SEE TEXT. A–14 REPRESENTS IN EXAGGERATED FASHION THE INFLUENCE OF DEFECTIVE NUTRITION IN CHILDREN.

The results are not directly traceable to simple deprivation of these essential elements of nutrition, but to the general metabolic disturbance initiated by the malnutrition (Fig. 1). The group of pig A–1 quickly succumbed; that of pig A–7 lived three months or so under the treatment and then died; pig A–14 lived six months or more, grew and put on weight, it is true, but was never robust and finally died from intercurrent disease to which its resistance was lowered by infirmity. The experiment, for which Dr. Milton B. Cohen was jointly responsible with myself, was started when the animals were nine weeks old. The columns in Fig. 1 register respectively in equivalents of chronological time the bone length (growth in dimension), physical maturity and weight of each animal at the beginning of the experiment and at its close in death. Where, as in A–1 and A–7, the disturbance of health was profound, weight fell off and growth was retarded, though maturation was not greatly inhibited. But in A–14 weight did not actually fall away. Weight, growth and maturation rate all were laggard, but maturation rate stuck most closely to the schedule based on the records of the healthy colony. This is the pig which most clearly illustrates my contention for infirmity in the young. Until the time when we abjure the comfortable, misleading doctrine of meaningless variations we shall not recognize the earmarks of infirmity. We must cease to rely upon standards of progress

in stature and in weight based on the great majority, especially upon those who are at or near the poverty line. The register of increment in height and weight must be checked against meticulous analytic studies of well children, longitudinal studies of children observed throughout their childhood and showing in their successful adaptation to food, to fortunate domestic circumstances and to their fellows a healthfulness for which all strive but few attain.[1]

I have spoken of maturation as distinct from growth. It is essential to grasp the significance of this distinction. A child not only grows; he grows up. The evidence of his growing up is recorded in his skeleton representing that part of the body which is clothed with skin without and supports the organs within. The skeletal register of maturation can be read by roentgenographic methods, a new branch of biological science only recently applied either to man[2] or animals[3]. Infirmity in childhood is recognized in many ways by those whose rationalization has not engendered an indifference to depreciation of the standards of health. It is chiefly obvious in failure to maintain that vigorous even progress in weight, in stature and in maturation which is characteristically apparent in a well selected group of really healthy children such as those to which allusion has been made in footnotes 1 and 2.

In middle life and still more in advanced age the changes characteristic of aging are so slow as to be almost unnoticeable, whereas those of disease or infirmity maintain their usual velocity. We distinguish the more rapacious disease from the less virulent infirmity but confuse the latter with aging of which we do not mark the evidence.

Aging is a process of adaptation both in structure and function. Structural adaptations are almost all completed by thirty years in man, but functional adaptations continue to be made. The impact of environment is met by changes in the organism. We call these respectively injury and repair. Aging in its functional aspect is therefore a continual repetition of injury and repair with repair dominant. By this physical experience we increase our tolerance, our resistance or, if you will, our immunity. Aging is the opposite of infirmity. But if something occurs to weaken the response to injury, aging is replaced by infirmity, since injury gains the upper hand in its struggle with repair.

This resistance against infection and toxic processes is developed in what we used to call the connective tissues of the body, a large part of which lies just under the skin. It is here indeed that the by-products of fatigue collect until they can be excreted. Hence the puffiness of the face in fatigue. As a matter of fact the subcutaneous connective tissue of the face illustrates very well the effect of repeated injury and repair. In the baby at birth the skin is not adherent to deeper structures at all. But in consequence of repeated puffiness and restoration there develops a scar tissue which by the time adult life is attained binds the skin to the deeper structures. A mask-like countenance with the wiping out of character by obliteration of the creases of health is the sign manual of weariness, infirmity or disease at all ages.

I have mentioned a definite upward limit to structural change. This occurs at different ages for different tissues. The child's brain is almost adult in form by the sixth birthday, his skeleton by the

[1] K. Simmons and T. W. Todd, *Growth*. In press. 1938.

[2] T. W. Todd, "Atlas of skeletal maturation." Part I—Hand. St. Louis, Mosby. 202 pp. 1937.

[3] Theodore T. Zuck, *Anat. Rec.*, 70: 389–399, 1938.

twentieth, his heart and muscles by the twenty-fifth. Nature is quite insistent on upward limits. After the whistle blows tools must down: another task must be undertaken. If the whistle blows before the task is completed tools must down just the same and structural incompleteness remains throughout life. This occasionally, though rarely, makes for weakness in defense or response because structural compensation usually provides against disaster. By its indomitable bias towards structural compensation, even after there has been marked interference with growth or maturation, the body makes an effort to readjust through enhanced growth or modification of proportions in the damaged area, always provided the damage done is not so great that the readaptation becomes impossible. The face is again a good example for, though its general lines are determined by heredity, the details of architecture in nasal form, jaw size and facial contour are modeled by fluctuations in bodily health.[4,5,6,7,8,9]

Structure, however, is merely the obvious expression of function. There must also, therefore, be upward limits of function. We do not know these well. In a man of sixty years a wound takes five times as many days to heal as a wound of the same size does in a child of ten.[10] Different tissues have different rates of dwindling in their power of response. Most of our organs are geared to last our time. Functional adaptation may dwindle or cease in skin, hair, teeth and nails without disturbing the rest of the body. But between skin without and the organs within is the body itself which obeys the will. It is this part of ourselves of which we are most acutely conscious, on whose health and power of repair we most depend. The tired business man is the tyrant of the family circle. As the heart goes with the muscles which it dominates, the brain goes with the body it directs. Whereas the body reaches adult size and maturity by about twenty years the heart is not fully mature till about twenty-five.[11] Hence the muscular system reaches its full power between twenty-five and thirty years, which is the age of sport championships in baseball, amateur golf, indoor tennis, boxing and marksmanship. The championship in outdoor tennis averages a little younger and that in golf a little older but not significantly so.[12,13] In industry as in sport the age of maximum efficiency immediately precedes thirty years.[14,15] The strength of a man of twenty-five years bears the same proportion to that of a man of sixty-five as the strength of the man of twenty-five bears to the strength of a woman of the same age in the same occupation. The upward limit in functional adaptation of the muscular system is determined, not in the muscles themselves, but in the cerebellum which coordinates muscular action. Ellis[16,17] showed that shortly

4 L. Dewey Anderson, *Angle Orthodontist*, 7: 142–149, 1937.

5 B. Holly Broadbent, *Angle Orthodontist*, 7: 193–208, 1937.

6 Milton B. Cohen, *Angle Orthodontist*, 7: 150–154, 1937.

7 Carl C. Francis, *Angle Orthodontist*, 7: 138–141, 1937.

8 T. W. Todd, *Angle Orthodontist*, 7: 131–137, 1937.

9 Theodore T. Zuck, *Angle Orthodontist*, 7: 155–157, 1937.

10 P. Lecomte Du Noüy, "Biological Time." New York: Macmillan. 180 pp. See pp. 154–155. 1937.

11 W. Erlich and A. E. Cohn, *Am. Jour. Anat.*, 49: pp. 209–240, 1931.

12 H. C. Lehman, *Abst. in Psych. Bull.*, 34: 764–765, 1937.

13 H. C. Lehman, *Sci. News Letter*, 32: 181, 1937.

14 W. A. Schochrin, *Arbeitsphysiol.*, Bd. 8, S. 607–609, 1935.

15 J. M. Ufland, *Arbeitsphysiol.*, Bd. 6, S. 653–663, 1933.

16 R. S. Ellis, *Jour. Comp. Neurol.*, 30: 229–252, 1919.

17 R. S. Ellis, *Jour. Comp. Neurol.*, 32: 1–33, 1920.

after thirty years there commence degenerative processes in the cells of the cerebellum which control muscular power and speed. The factor which modulates the vigor of response is found not in the instrument of that vigor but in the governor itself.

This is the cardinal theme of life in advancing years to-day. The statistical evaluation of our destiny is of comparatively little import. That, out of twenty adult men and women, five must die of cardiovascular disease, three of respiratory involvement, two of cancer, one of violence and nine of other numerically less frequent maladies[18] is interesting, no doubt. But it has little meaning for us who live. We are not concerned with death which, as a natural process of elimination, provides that the withered leaves of autumn become the wet nurses of the spring. What is important to us is the fulness of our life, the joy of hopefulness and self-reliance, the health of mind and body which spell fortitude, control and tolerance, the spirit which seeks and seizes opportunity and revels in success. We see it all portrayed on the advertisements in the street cars and the illustrations in popular magazines. Do we feel it in ourselves as we set out for the office or the shop? Do we meet it at home in the evening when the frivolous activities or distracting occupations of the day have ceased to enliven hope and conceal our true feeling? If not, it matters little that we are assured of organic soundness: we have exchanged aging for infirmity: the warning that we might heed is already displayed: the storm signal is out which none but the doomed would affect to deny.

A new chapter will be written into medicine when the criteria of healthy aging replace those standards of youth which serve us to-day. We are told[19] there are so far no effective standards of malnutrition in childhood; they are still to be discovered. The truth is rather that no one criterion is all-inclusive, for it is not in the physical structure that we should expect to find objective evidence of the first deterioration of health, but in those morbid moods which tarnish the joy of living and particularly the irascibilities and impatience of fatigue.

Criteria of healthy aging are of necessity different from those of youth. Our elasticity and resilience are lessened by the honorable scars of resistance and repair. Our speed of reaction may be curtailed, though alertness and grace remain. Staying power is more readily diminished and creative imagination more easily curbed by fatigue. Nevertheless, the portents of disaster are the same throughout life.

Fatigue, apprehension, despondency, are the signals set to warn us when we must take steps to maintain constructive healthy aging and not fall into the clutch of infirmity. The very scaffolding of intellect gives way if its load of morale is overstrained. Intelligence, unhampered by bodily fatigue, can sort and sift. It possesses the power of imagination which enables it to visualize future possibilities and make a plan which, granted physical health, it delights to carry out. We are concerned by the tragedy of recognizable disease which cuts off a man before his time, but we should be infinitely more moved by the pathos of a tragedy which cripples seven out of every ten of the so-called healthy men and women who have docilely accepted the substitution of infirmity which they might have avoided for aging, which is their birthright.

[18] M. Lawrie, "Nature Hits Back." London: Methuen. 180 pp. See pp. 156–7. 1936.

[19] Kenneth Fraser, *Manchester Guardian Weekly*, 35: ii. May 17, 1935.

Summary

(1) Biological change must not be confused with chronological time. We note the former only when its speed is great against a background of the latter, as in the growth of childhood, the ravages of disease and the progress of infirmity.

(2) In middle life and still more in advanced age the changes characteristic of aging are so slow as to be almost unnoticeable, whereas those of disease or infirmity maintain their usual velocity. We distinguish the more rapacious disease from the less virulent infirmity but confuse the latter with aging, of which we do not mark the evidence.

(3) Aging is a process of adaptation both in structure and function. Structural adaptations are almost all completed by thirty years in man, but functional adaptations continue to be made. The impact of environment is met by changes in the organism. We call these respectively injury and repair. Aging in its functional aspect is therefore a continual repetition of injury and repair with repair dominant. But if something occurs to weaken the response to injury, aging is replaced by infirmity, since injury gains the upper hand in its struggle with repair.

(4) Different tissues have different rates of dwindling in their power of response. Most of our organs are geared to last our time. Functional adaptation may dwindle or cease in skin, hair, teeth and nails without disturbing greatly the rest of the body. But between skin without and organs within is the body itself, which obeys the will. It is this part of ourselves of which we are most acutely conscious, on whose health and power of repair we most depend.

(5) Criteria of healthy aging are of necessity different from those of youth. Our elasticity and resilience are lessened by the honorable scars of resistance and repair. Our speed of reaction may be curtailed though alertness and grace remain. Staying power is more readily diminished and creative imagination more easily curbed by fatigue. Nevertheless, the portents of disaster are the same throughout life.

THE GENERAL FORMAL EDUCATION OF EMINENT MEN

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From many sources has come evidence that persons who stand out above their fellows in the degree of their social recognition are above the average of the general population in length and quality of education. And the same thing in general has been true of the corresponding class of historical personages, as well as the greatest geniuses. Such superiority is a corollary of superior economic and occupational rank of the parents of such persons and of the persons themselves, on the one hand, and of the superior ability to benefit by an education, on the other hand. The facts of superiority are contrary only to the conception of members and former members of the lower classes who believe that outstanding people as a class are able to climb to the top of the social scale and make great achievements without any guidance from other people. However, all students of eminence and leadership, even those who use the hereditary interpretation of the facts, admit that the self-educated person is more unusual than usual and that the highly educated man is the average rather than the exception, even among the persons of the highest historical importance.

Of the sources of educational influence in the broadest sense of that term, three stand out on which sufficient information exists for useful analysis. The first is informal education of the home, the second formal education in lower and higher schools, and the third special education of the order of professional training. The present article will be concerned with only the second of these types of educational background.

In the relative numbers of 185 great leaders who were educated in a variety of ways we have a rough indication of the importance of various sorts of education. These preeminent historical figures were among the one thousand most eminent persons of the last few centuries and included no living persons. Fifty-one received classical training, 102 (55.1 per cent) college or university training, nine received a "limited education," three received "no formal education," ten received "slight education," and ten were "self-educated." Only 13 were without formal education, compared to 172 who received some degree of education, or roughly a ratio of 13 to 1.[1] Compared to the educational advantages of the average citizen in the same period, the eminent men were very greatly superior, although the degree of superiority is not known in statistical terms.

Data from Havelock Ellis's study of British leaders are not entirely comparable to those mentioned, since Ellis included data on only those with university training. This one item, however, is in close agreement with the international data; 53 per cent.[2] compared with 55.1 per cent. It is of interest to note that Ellis's list included persons less eminent than those in the study by Cox.

Turning now to studies of contemporary notables, we have from "Who's Who in America," 1934–35, statistics on 29,389

[1] C. M. Cox, "The Early Mental Traits of Three Hundred Geniuses," Stanford University, 1926, *passim*.

[2] Havelock Ellis, "A Study of British Genius," Revised Edition, Boston, 1926, pp. 127–128. Maclean's study, mentioned by Ellis, revealed roughly comparable data.

individuals reporting educational background, of whom 74.7 per cent. were graduated from higher educational institutions, 86.5 per cent. had attended such institutions, and 92.8 per cent. had attended high schools or their equivalent.[3] Other studies of contemporary persons eminent in various occupations also show a close relationship between education and eminence. For example, Lott found that 43.5 per cent. of 1,178 Montana urban leaders were college graduates, 59 per cent. had attended college, and 76.5 per cent. had attended high school.[4] This study shows less relationship between education and prominence than was found in the other investigations, but that may be due in part to the recency of the settlement of Montana, which would probably put less premium upon formal education than would be true of the average state which has a longer history. Davies, on the contrary, found that a correlation coefficient of .98 best expressed the degree of relationship between college education and attainment of national distinction by persons listed in "Who's Who in America," 1912–13.[5]

TRENDS

The most complete data showing trends in the educational experience of eminent men are from "Who's Who in America" (Table I). The significant fact is the rapid increase in the proportion of college graduates since 1916, especially from 1923 to 1929. Before 1916 the proportion had varied between 57.4 and 61.4 per cent. College non-graduates have varied within limits of 15.5 and 11.6 throughout the thirty-five years covered by the data. The proportion who had no more than secondary education rose consistently from 1899 to 1910 and declined steadily after 1916. The proportion of those with only common school education declined after 1910 until 1928. The proportion of those who were self-educated rose to a peak in 1910 and declined to the lowest point in 1928, but 1903 was the year of second lowest number of those self-educated. Private educated declined in importance

TABLE I

PERCENTAGE OF PERSONS LISTED IN "WHO'S WHO IN AMERICA" REPORTING DIFFERENT TYPES OF EDUCATIONAL BACKGROUND

Last educational status attained	Year							
	1899[a]	1901[a]	1903[a]	1910[a]	1916[b]	1922[c]	1928[d]	1934[e]
College graduation	58.2	61.4	57.4	57.9	59.2	63.7	74.3	74.7
College attendance without graduation	15.5	12.3	15.0	13.2	13.7	13.7	11.6	11.8
Total college attendance	73.7	73.7	72.4	71.1	72.9	77.4	85.9	86.5
Secondary education[f]	15.7	16.0	17.6	18.9	18.1	14.1	7.4	6.3
Common or Public School Education	10.6	10.3	10.0	10.0	9.0	8.5	6.7	7.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total Cases in Series.	**6,024**	**7,838**	**11,119**	**15,518**	**20,115**	**22,075**	**26,758**	**29,389**

[a] Data from "Who's Who in America," 1910–11, p. xxiii.
[b] "Who's Who in America," 1918–19, p. 26.
[c] "Who's Who in America," 1924–25, p. 26.
[d] "Who's Who in America," 1930–31, p. 22.
[e] "Who's Who in America," 1936–37, p. 18.
[f] Includes secondary, high school and normal school education. In earlier periods all normal school students were classed as persons having secondary education. In the 1928–29 and 1934–35 editions normal school students from accredited schools were classified with college and university students.

[3] "Who's Who in America," 1936–37, p. 18.

[4] E. H. Lott, "Rural Contributions to Urban Leadership in Montana," *Montana State College Agricultural Experiment Station Bulletin*, No. 262, 1932, p. 29.

[5] G. R. Davies, "A Statistical Study of the Influence of Environment," *The Quarterly Journal of the University of North Dakota*, 4, 1913–14, 226.

from the period of 1903, with the lowest proportion in 1928.[6]

Evidence from a study of prominent business men bears out this trend. Most of the older group of men studied by Taussig and Joslyn were not college men, while most of the youngest were. There was an almost perfectly regular increase in proportions of those who had college education, as the average age of the groups decreased. And there was a corresponding decrease in the proportions with no formal education, grammar school, and preparatory school education. Of the group from 50 to 54 years of age, 32.6 per cent. were college graduates, 46 per cent. had attended college, only .6 per cent had had no formal education, and only 26.8 per cent. had had no more than a grammar school education. Of those who were from 30 to 34 years of age, 43.7 per cent. were college graduates, 67.9 per cent. had attended college, .3 per cent. had had no formal education, and 10.9 per cent. had had no more than a grammar school education. In comparison, of those men who were 75 years of age and over, only 15 per cent. were college graduates, only 26.5 per cent. had attended college, 1.8 per cent. had had no formal education, and 39 per cent. had had no more than a grammar school education. Although due allowances were made for various factors that would account for the trend besides actual tendency for more business leaders to be college trained, the conclusion that a real trend was displayed was retained.[7]

Evidence from the 1924–1925 "Who's Who in America" shows that the average age at graduation from college was below that for the general college graduate,[8] a fact even more important when one considers that the average age of college graduates to-day is probably somewhat smaller for all than it once was.

Nearing's study of 2,000 persons listed in "Who's Who in America, 1914–15, whom he considered to be representative of the "younger generation of American genius," revealed the fact that 77.4 per cent. had received a four-year college education, 86.9 per cent had attended college, and only 13.1 per cent. had had no college education.[9] This group would correspond roughly in year of birth to the later studies of educational origins of persons listed in "Who's Who in America." And there is little difference between Nearing's figure for those who had attended college for at least a short time (86.9) and the corresponding figure for the total number of persons in "Who's Who in America, 1934–35 (86.5 per cent.). The other figures for these two analyses are also very similar. This is not surprising since any person born before 1869, which was the earliest date of birth of cases included in Nearing's second study, would be nearly sixty-five years of age at the time of the publication of the 1934–35 edition of "Who's Who in America," which is more characteristic of the age of the rank and file of prominent Americans than the average age of those under forty-five years of age.

Further evidence of the same sort is available from "America's Young Men," the new biennial list of important men most of whom are under forty years of age. In the first edition (1934–35) 95.2 per cent. had attended college and 86.9

[6] These statements are substantiated by data included in the various analyses of educational reports on "Who's Who in America" data already mentioned. The numbers were not given for 1934–35 and throughout have been so small that there was no need of including them in the tabulation. The self-educated were as follows: 1899–20, 1901–31, 1903–24, 1910–67, 1916–77, 1922–58, 1928–39. Figures for private education were: 1899–185, 1901–282, 1903–446, 1910–209, 1916–282, 1922–331, 1928–367.

[7] F. W. Taussig and C. S. Joslyn, "American Business Leaders," New York, 1932, pp. 163–166.

[8] J. S. Cleland, "Age of Graduation and Success in Life," *School and Society*, 21, 1925, 31–32.

[9] S. Nearing, "The Younger Generation of American Genius," SCIENTIFIC MONTHLY, 2, 1916, 54.

per cent. were college graduates, while in the second edition (1936–37) 97.3 per cent. had attended college and 88.3 per cent. were college graduates.[10] The trend toward perfect agreement between prominence and college education thus continues on in accordance with past developments. In view of the fact that Nearing's percentage for younger leaders with college education in 1914–15 was almost identical with that for all leaders twenty years later, it seems possible to predict that the "Who's Who in America" group in 1954–55 will be almost uniformly from a college background. This prediction at first glance does not appear to be as sound as one based on the younger persons (those under forty-five years of age) in "Who's Who in America," but the method of compilation of "America's Young Men" appears to be so comparable to that of "Who's Who in America" that the prediction seems justifiable.

Any interpretation of trends must take into account the trend toward increased college education in the United States. This trend for the United States from 1880 to 1920, which embraces part of the trends shown in the "Who's Who in America" data and in Taussig and Joslyn's data, was from 687 male college graduates per 100,000 males twenty-two years of age and over for 1880 to 1,137 in 1920.[11] This is an increase of more than 65 per cent., a figure considerably greater than the increase in the percentage of persons listed in "Who's Who in America" with college education, but at the same time considerably short of the rate of increase required to keep pace with the rate of increase of the college education of the subjects of Taussig and Joslyn's study accompanying the decrease in the age-range. The national trend toward more education is thus at least a partial explanation of the trend toward the possession of more formal education by prominent men of the present generation. But there is still an increase that must be accounted for in other ways, the most probable explanation being an accelerating educational selection in prominent positions, although there may be an actual increase in the influence of education upon the rise to positions of prominence.

Sex, Education and Eminence

The most recent data available on the educational background of women listed in "Who's Who in America" indicate that a somewhat smaller percentage are college trained than is true of men. Only 52.0 per cent. of the 1,622 women on whom sufficient data were given were graduated from college and universities or their equivalents. An additional 19.1 per cent. attended college without graduating, making a total of 71.2 per cent. with some education in college,[12] compared with 74.7 per cent. graduates and 86.5 per cent. with some college training in the total "Who's Who in America" group. It is thus obvious that proportionately fewer of the most outstanding women have received college education than is true of men of the same degree of recognition.

For a somewhat larger number of women which included persons of a lower degree of social recognition than the "Who's Who in America" listing the percentage of college graduates was 64.2 and those with some college training was 81.9.[13] Thus women at a lower level of

10 "America's Young Men," 1936–37, p. xiii.

11 J. P. Shaw, "Statistics of College Graduates," *Quarterly Publication of the American Statistical Association*, 17, 1920–21, 337.

12 "Who's Who in America," 1936–37, p. 2704.

13 "American Women," 1937–38, p. xxi. The percentages are not strictly comparable because the biographies with insufficient data were not eliminated from the latter group. The superiority of educational background of the less restrictive group was greater when total women college graduates and with some college education are related to total women in the lists. Of all women in "Who's Who in America," 1934–35, only 43.2 per cent. specified college graduation, and only 59.1 per cent. specified some attendance at a college or university.

social recognition are more similar to men of a given degree of recognition in degree of education than they are to women of the given degree of recognition. Stated another way, American women appear to exhibit an inverse relationship between degree of recognition and degree of education. In view of the change in educational background for the total Who's Who in America" group over a period of thirty-five years, it seems likely that the difference between the educational background of women of different levels of recognition will prove transitory and is largely due to age. One test of this hypothesis would be to study a sample of the women at any level of recognition in order to determine if there is an educational superiority for the younger generation, that is, for the group that will later, for the most part, constitute the women of highest recognition. The argument is based on Nearing's discovery that the younger persons in "Who's Who in America" had superior educational background to the older ones and a background very similar to the present "Who's Who in America" population.

Another study that would shed some light on the same question is a comparison of the education of the most eminent 2,000 men in the United States with that of the same 2,000 plus the next most eminent 4,000 men. This would give comparable figures in proportion to the male population of comparable age to those obtained from the women of "Who's Who in America" and the women of "America's Women." It should be expected on the basis of the age hypothesis mentioned above that the higher education for the most prominent persons of each sex would be less than that for the least prominent. If such a study should show less education for the more than for the less prominent men, this might be interpreted as evidence that college is of minor importance for social recognition. But evidence of such a sort would not be conclusive because of the differential opportunity and stimulation of the older and younger personages for college education. Not until this element of the changing educational situation is eliminated by the passage of time or by some means of statistical control, can such studies offer evidence on the importance of college education for eminence. This will be mentioned again later.

Trends in the education of eminent women are of great importance for any sound interpretation of sex differences in the education of the prominent. Data are by no means as complete as for the total group of eminent personages. In the 1901–02 edition of "Who's Who in America" only 15.5 per cent. of the women listed had graduated from colleges and universities,[14] compared with 59.1 per cent. for the total group. The figures were 23.8 per cent. for women[15] and 56.0 per cent for the total in 1903, compared with 52.0 per cent. for women[16] and 74.7 per cent. for the total in 1934. The total percentages with some college education are available for more of the intervening editions. In 1903 the figure for women was 32.3 per cent. compared with 69.8 per cent. for the total.[17] In 1920 the percentage for women was 58.5[18] and for the total in 1922 was 77.4. By 1930 the women had gained even more ground.

[14] Amanda C. Northrup, "The Successful Women of America," *Popular Science Monthly*, 64, 1904, 243.

[15] "Who's Who in America," 1903–05, p. xx. Percentages based on a distribution including self-education and private education. Cf. Table I.

[16] "Who's Who in America," 1936–37, p. 18.

[17] "Who's Who in America," 1903–05, p. xx. Cf. footnote 15, above.

[18] S. S. Visher and Gertrude Haverstock, "Who's Who Among American Women," SCIENTIFIC MONTHLY, 15, 1922, 447.

The percentage was 76.8[19] compared with 85.1 for the total in 1928. In the 1934–35 edition women with some college training declined in proportion to 71.2 per cent.[20] compared with 86.5 per cent. for the total. The upward trend for women has been very pronounced except in the last period, the ratio for college graduates changing from slightly more than 1 to 4 in 1901 to 1 to 1.4 in 1934. Correspondingly the ratio for those attending college changed from 1 to 2 in 1903 to 1 to 1.2 in 1934. The present difference between the sexes is not great and probably reflects the differential education of the sexes at the present time, just as the rapid change of ratios reflects the increasing tendency for women to obtain college education during the last 30 years.

Education and Chances for Eminence

Several well-known students of eminent men have placed the chances for eminence of those with college education at more than one hundred times as good as those who had not received such education. Davies in 1917 concluded that chances were 196 times as great for college graduates as for the person who had not graduated from college.[21] Clarke's data were interpreted to mean that even more chances for becoming eminent men of letters were possessed by college-trained than those not educated in colleges.[22] Other studies containing data on education can be similarly interpreted.

The reasoning in support of the statements of differential chances for recognition on the part of persons with a particular educational background is based on the ratio of college graduates (or persons with a particular educational background) listed in "Who's Who in America" (or some comparable list) to all college graduates living at a given time, as well as on the ratio of the persons not graduated from college but listed in "Who's Who in America" to all persons living at the same time who had not graduated from college. By use of some estimates made by Shaw concerning the number of surviving college graduates in the United States in 1900, 1910 and 1920,[23] together with educational data from "Who's Who in America" for comparable years (1899, 1910, and 1922) it is possible to supplement previously existing knowledge. Of the 164,485 college graduates surviving in 1900, a total of 3,508 were listed in "Who's Who in America," 1899–1900, or one to every 46.9. Subtracting the 164,485 college graduates from the total males above twenty years of age in the United States in 1900, a total of 21,705,463 is obtained. Of these persons 2,586 were listed in "Who's Who in America," 1899–1900, or a ratio of 1 to every 8,393.4. The ratio of these ratios, in other words, the relative chances of college graduates and persons not graduated from college for inclusion in "Who's Who in America" at the turn of the century, was 179 to 1 to the advantage of college graduates.[24]

[19] A study by Eva M. Pletsch, quoted in "Who's Who in America," 1932–33, p. 26. Also see Bertha Beach Tharp, "Relation of Education to Success of Eminent Women," Scientific Monthly, 37, 1933, 134–38.

[20] "Who's Who in America," 1936–37, p. 18.

[21] G. R. Davies, "Social Environment," Chicago, 1917, p. 113.

[22] E. L. Clarke, "American Men of Letters; Their Nature and Nurture," *Columbia University Studies*, 72, 1916. The statement is "several hundred times," p. 68, although no statistics in support are given.

[23] Shaw, *op. cit.*, p. 339.

[24] The ratios contain certain errors, because estimates of surviving college graduates had to be employed. The more serious errors arise from the following facts: 1. The number of surviving graduates was estimated on the assumption that college graduates have the same survival rate as the general population of the same age and sex. This is undoubtedly not correct, but the precise advantage of college graduates in survival rate is not known. 2. The "Who's Who in America" group, containing a small percentage of women (ranging between 6 and 9 per cent), was related to the male population of the country. 3. The age of college graduates was assumed to be 22 years and over in making the estimates of

Corresponding figures for both 1910 and 1920 were 160 to 1 (Table II). The resulting series for three decades is not long enough to indicate a trend on which much dependence can be placed, and there are no data on number of college graduates living later than 1920 yet available for the extension of such a series. On the basis of college enrollment up to 1930, however, it is clear that college graduates have been increasing in proportion more rapidly than the combined increase in the number of persons listed in "Who's Who in America" and the increased percentage of "Who's Who in America" personages who are college graduates.[25] Consequently, it is certain that the advantage with the college graduate has been reduced. In other words, college education has been extended to increasing numbers of people who, because of the relatively large numbers in relation to the positions of the highest social importance, cannot hope to be entered in the list of the most outstanding persons unless that list is broadened. Again, such a trend signifies that college education does not mean as much for eminence as it once did in this country, unless the definition of eminence is extended to more people. This is in spite of the increasing percentage of persons listed in "Who's Who in America" who have college training. In spite of the decline, it is obvious that the advantage for the college graduate will remain very large for a long time, and can never entirely disappear under the present social and educational order. And it is also worth pointing out that social contribution is not always in pro-

TABLE II

RELATIVE CHANCES OF COLLEGE GRADUATES AND ADULTS NOT GRADUATING FROM COLLEGE FOR INCLUSION IN "WHO'S WHO IN AMERICA," 1900, 1910, 1920

Year	No. College Graduates in "Who's Who in America"	No. not College Graduates in "Who's Who in America"	Year	Estimated No. of College Graduates Surviving[c]	Male Population 20 Years of Age and Over not College Graduates[d]	Ratio of College Graduates in "Who's Who in America" to Total College Graduates	Ratio of Those in "Who's Who in America" not College Graduates to Total Male Population 20 Years of Age and Over not College Graduates	Number of Chances of College Graduates to 1 Chance for Those not College Graduates of Being Listed in "Who's Who in America"
	1	2		3	4	5	6	7
						(Column 3) / (Column 1)	(Column 4) / (Column 2)	(Column 6) / (Column 5)
1922–1923	14,055[a]	8,020[a]	1920	358,026	31,888,945	25.5	3,976.2	160
1910–1911	8,985[b]	6,633[b]	1910	233,957	27,664,566	26.0	4,170.7	160
1899–1900	3,508[b]	2,586[b]	1900	164,485	21,705,463	46.9	8,393.4	179

a "Who's Who in America, 1924–25, p. 26.
b "Who's Who in America, 1916–17, p. xxv.
c Shaw, *op. cit.*, p. 339.
d Population data from Census of 1920, vol. II, p. 154.

surviving graduates, but population data included persons over 20 years of age. In spite of these shortcomings in the calculations, the resulting ratios are in all probability substantially correct, and the data presented below on other decades are directly comparable, although not perfectly accurate.

[25] With a total of approximately 38,000,000 males in the United States over 20 years of age in 1930, and approximately 7,000 persons in "Who's Who in America," 1928–29 who were not college graduates, compared with less than 20,000 college graduates in "Who's Who in America," in order to retain the ratio of 160 to 1, less than 700,000 living college graduates would be required. Such a figure is far too small in view of the total of more than 900,000 students enrolled each year from 1927 to 1930 and more than 90,000 graduates each year after 1925, in addition to surviving graduates of varying ages.

portion to the recognition that a man is accorded, which is to say that chances for social contribution remain and will remain after chances for attaining the highest rank and recognition have declined.

Summary and Interpretation

In summing up the data on the amount of education of eminent persons, four conclusions are most obvious. First, whether small lists of the most eminent world-historical figures, somewhat less restricted lists, or lists of contemporary notable persons of the United States are employed, a high degree of education has almost always been possessed by the prominent person, and also a degree superior to that possessed by the rest of the population. Second, trends toward more advanced education and away from lower limits of education and from self-education are quite clear-cut. And there is no indication that this stage has been completed. Third, at the present time there is only a small sex difference in the education of persons in "Who's Who in America. Men surpass women in the proportion who have attended college and in the percentage who did not have as much as a common school education. The college training of women in "Who's Who in America" has increased at a more rapid rate than has that of men. Fourth, a man with a college education has many more chances for eminence than one whose education was not extended beyond a lower level. The relative advantage appears to have declined and is likely to continue to decline for at least a short time into the future.

Although these conclusions for eminent persons in general indicate a close association between education and the attainment of eminence, it is still a question in the minds of many whether education is responsible in any way for eminence. The specific suggestion has been made that the association is based on a selective factor rather than the contribution from education to achievement and recognition. According to this interpretation people who obtain formal education at the college level—although the theory would apply at all levels of formal education—have certain qualities of mental capacity and personality as well as opportunity to go to college. These persons also have important qualifications for eminence; indeed, perhaps the qualifications that enable young people to acquire formal education are those that enable them to rise to positions of prominence. The result is that those who would most likely become eminent because of qualifications not due to formal education, *per se,* are those who are most likely to obtain that formal education, thus confusing the causal factors.[26] The education itself, according to this theory, contributes nothing but confusion to the analysis of causation.

At present there is very little evidence concerning the true explanation of the relationship discovered. Taussig and Joslyn argue that the presence of superior proportions of college men in the larger business organizations does not prove the positive effect of college education, because there is no positive evidence of the effect of general school training on vocational achievement. They turn, for this reason—and perhaps also because of their preconception, since it is not necessary to make any final interpretations—to the theory that, because the men less competent for business achievement are elminated in the earlier levels of the institutional organization, the men educated in college are more prevalent in business positions of the sort studied than those who were not so educated. And by the same sort of reasoning, it is said that

[26] *Cf.* Lott, *op. cit.*, p. 31, and Taussig, and Joslyn, *op. cit.*, pp. 166, 187–188 for such statements.

college men succeeded both in college and in business because of their general superiority and not because of what they learned in college.[27]

Such a view is certainly contrary to the interpretations of most educators, as well as to those of most students of eminent men. Nevertheless, something more than an assumption concerning the contribution made by education is required to support the correlations between eminence and education, and to refute the selectionist theory. If it can be shown that the individual gains something from the educational experience that he would not have gained otherwise and which is necessary for eminence, then the importance of education will no longer be in question. This is not easy to do, because of the interrelations of selective and contributive factors in every situation and for every person. Education in schools has not been necessary for the development of most of the greatest men of any historical period, if by greatest is meant the foremost ten of twenty. So far as we know every man who made great achievements and obtained great recognition, and who also had a formal education would have had essentially the same career if he had been associated with the same people during the same length of time and had obtained the same amount of prestige from the experience that was obtained by attendance at some college, university, or other school. The things that make education formal, in short, may have had nothing whatever to do with the result. But such statements as the above indicate some things of unquestionable importance that education does in a shorter length of time and more uniformly than can be done in other ways, and this may be true under favorable conditions for even the more able intellects. In the first place, formal education gives students opportunities for contacts with experts along certain lines, experts with whom the potential man of achievement might only with difficulty come into contact outside of the institution. Second, the period of time required to obtain the basic fundamentals of subjects is shortened by the organization of the curriculum, especially in places where there is flexibility for the benefit of the more able student. Third, it gives proportionately more leisure for study than can be obtained in any other way for large numbers of people. Fourth, it gives companions in study, opportunities for discussions, and the joint solution of difficulties. Fifth, entreé to the leading persons in certain fields is gained through colleges and universities either directly or indirectly through contact with lesser personages. And sixth, educational experience, especially in certain institutions and in certain grades or qualities of work within the institution adds to the individual's prestige in such a way that he makes faster progress toward recognition afterwards.[28]

It might also be thought at first glance that the direction of interests of persons of talent is a major contribution of the school. This does apply to lesser individuals, but many of the most illustrious persons had such definite interests so early in childhood that the school cannot be given credit for their development. The personages, of which this statement is most true are scientific, philosophical, musical, artistic, and literary notables, although eminent men tend to choose

[27] Taussig, and Joslyn, *op. cit.*, pp. 187–188. The theory of selection in education is old, and has been advanced by many sociological thinkers. See P. A. Sorokin, "Contemporary Sociological Theories," New York, 1928, Chapter V, and "Social Mobility," New York, 1927, p. 187 ff.

[28] *Cf.* Sorokin, "Social Mobility," pp. 169–172 for a discussion of education as a channel by means of which one rises to prominence. Prestige is one of the main factors defining the usefulness of a channel.

their careers earlier than the average person.

A glance again at the list of positive advantages of formal education makes it clear that there are conditions under which these gains are immaterial in comparison with the favorable circumstances of extremely fortunate individuals. The son of a foremost philosopher or scientist in an age of a low degree of specialization, or the son of a wealthy and brilliant father with a fine private library offer examples. Contact with experts, prestige from personal contacts, leisure, period of time required to learn the fundamentals are all present in superior degrees. And the stimulation of a more mature mind and personality is not at all rare. This combination was fairly common among the eminent personages of history. However, such a fortunate situation was always rare and is now even more difficult to attain, mainly because of the tremendous advances in all fields of knowledge, the great amount of specialization required for achievement in most fields of activity, and the phenomenal increase in the published materials that are beyond the scope of private libraries. Self-education is still possible in extreme instances, and education within the family is still possible as a first step to achievement along many lines, but with the advancement of specialization such opportunities are found to decrease, until it is possible that even the most favorable arrangement of circumstances outside of colleges and universities will fail to produce a great scientist and other types of leaders. Such at least appears to be the meaning of specialization in the fields of science and the technical advances in all of them away from interest in surface and common-sense aspects of the world.

The position that careful consideration forces us to take is thus that formal education is generally of importance in accounting for eminence. It is of more importance than the selectionists usually are willing to admit, but at the same time it is less important than the average educator will admit. Furthermore, the interrelations between the factor of formal education and the other factors in eminence are far more complex than is ordinarily believed. And finally, formal education's importance is dependent in part on the cultural situation and the sort of eminence under consideration. It is more important to-day in many fields than formerly and has not reached the limit of development. And it is always likely to be more important in fields of great specialization and removal from the level of activities of the ordinary world than in other phases of endeavor.

SPRINGTIME AND SALAMANDERS

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EVERY man, no doubt, has his own sign of spring's true arrival. Here in Baltimore it is apt to be the first hobo selling flowers in the street or perhaps the first crocus in the archbishop's garden. But for many biologists—and who should be more concerned with spring than they?—the advent of this loveliest of seasons is marked by an event almost no one ever sees. It is an event, none the less, which initiates weeks of feverish activity in many university laboratories and which is itself nearly as common as skunk cabbage and pussy willows.

This little understood phenomenon, so full of the mystery of spring, is the annual breeding migration of a salamander, the salamander which lays the eggs that are the modern equivalent of Louis Agassiz's famous turtle eggs.

Doubtless for the present day laboratory worker to witness the actual migration or the breeding behavior which follows is no more necessary than it would have been for Agassiz to have seen the turtle which laid the eggs Mr. Jenks, of Middleboro, collected for him so long ago. It would be much easier, however, for any one to observe the breeding of the salamanders than it was for Mr. Jenks to catch that turtle depositing her eggs. The salamander involved, *Amblystoma punctatum,* is one of the most abundant of the animals inhabiting the woods over a large part of the United States. Indeed, this migration which presents essentially the same problems involved in the migrations of birds or butterflies, can be studied close to most of our largest cities.

The reason so few people realize how common these animals are is that very few men, even very few naturalists, have ever seen an Amblystoma except on one night in the year. That night is the night on which they come down to the ponds, and very special ponds at that, to breed. At such a time you can see them in hundreds, sometimes in thousands, crawling and swimming over the usually leaf-covered bottom.

Amblystoma themselves are vigorous though just slightly awkward creatures about six inches long which greatly resemble plump and smooth-skinned lizards. Usually they are glistening ebony black with a row of bright yellow spots along each side and extending forward onto the blunt-nosed head. The effect is not unlike that of the lighted portholes of a ship. Exactly how these sturdy animals live during the remainder of the year is as yet largely unknown. Their obscure destinies probably lead them under the fallen logs and tangled débris which covers the floor of the woods adjacent to their chosen pond. Several, it is true, have been found during excavations far from any body of water. Certain it is that they shun the light, and it is entirely possible that they are nocturnal, emerging on dark and rainy nights to forage for earthworms and crickets or other small prey. This last, however, is speculation.

But there is no uncertainty about the fact of their annual migration nor does there seem to be any doubt in the minds of the salamanders themselves as to the date on which it is to take place. This is all the more remarkable because like Easter it is an elusive and movable feast. The best human prediction is about as reliable as your grandfather's almanac. "On the night of the first good rain after the first real thaw in spring." You are

not expected to ask how much rain is a "good rain" nor what constitutes a "real thaw." Only the Amblystoma know the answer to these or to any one of a dozen other puzzles which arise from erratic spring weather conditions. Perhaps, as has been determined for the oyster, there must have been a certain minimum temperature maintained for a certain minimum time before the breeding reactions will occur.

In general, by the night the salamanders start their migration the ice has melted from around the edges of the pond, although some remains in the center and in out-of-the-way corners. Often along the moist bank skunk cabbage has begun to force its way up through the dead leaves. At the same time the wood frog, the earliest frog to spawn, is just waking from its hibernating sleep and appearing in these same localities.

Considerable perseverance is apt to be required to see the migration. One night too early and you will see nothing. One night too late and the big show is over. The only way which never fails is to inspect the selected pond equipped with flashlight, boots and raincoat, every rainy night, the darker and rainier the better, beginning very early in the spring before there is any question of a "good thaw."

On the right night, if the thaw has been a real one and the rain good, you will see on the bottom which on all the previous nights was deserted save for a stray water mite or two, a writhing mass of spotted salamanders milling around in a frenzy of cold excitement. So numerous are they and so unconscious of all but one dominant impulse that you can reach down into the icy water and catch them without the aid of any net. On this first night they prove to be almost exclusively males. If you sweep the banks with your flashlight you will surprise other males, sometimes at a considerable distance from the water, but on their way down to the pond where they will join the throng of glistening black animals with bright yellow spots. The dance continues hour after hour.

The next morning the pond will again be deserted, so completely deserted that you are forced to wonder whether or not you really could have seen what you remember from the night before. Overturning half a dozen partially submerged logs or rocks will reveal no confirming evidence in the form of salamanders. But out on the floor of the pond where the excitement was at its greatest are multitudes of what appear to be little pinches of white cotton attached to submerged leaves and sticks. These little flecks of white, not quite the size of your little finger nail, are the spermatophores, packets of sperm which the males have left behind them and which are now waiting for the females.

Picked up and examined, they appear to be composed of a whitish jelly-like material which when torn apart will release the spermatozoa. Under the lens of a compound microscope each sperm is a creature of amazing and delicate beauty. The head is the shape of an exquisitely fine and slightly curved needle. From it extends a long slender thread, the tail. Along the side of this tenuous and slowing waving tail runs an undulating membrane so delicate that it is visible only when the light of the microscope is adjusted with the utmost nicety. Then it reveals itself by its rapid and never ceasing series of undulations arising at the head and increasing in amplitude as they pass back towards the end of the tail. It is by means of this tail that the sperm swims.

If the rain continues and the next night is dark, females, driven also by some unknown force, will appear in the pond. Sometimes of course it will clear and the pond freeze tight, thus delaying the females a week or even longer. But the

sperm packets remain and when the females do arrive something leads them to seek out the spermatophores which the males have left and insert them into their reproductive tracts. It amounts to artificial insemination, a feat which man has only recently achieved. Presumably there is some secretion, possibly some enzyme, in the female's cloaca which dissolves the jelly and releases the sperm. In any case, even though the female Amblystoma usually never sees the male, the actual fertilization of the eggs takes place within her body. Of course there are many salamanders like the common greenish yellow pond newt which do have an elaborate and even rather rough courtship. But this is not the case with Amblystoma. The sperm-packet depositing ceremony is a strictly stag affair. For several days after the original male migration a few individuals of both sexes can often be found in the same pond on the same night and on one occasion I saw a pair pass each other on the bank, the male going away from the water, the female toward it. Yet under all these circumstances they remain completely indifferent to each other.

Of the actual nature of the instincts and tropisms which bring about this migration and breeding reaction we at present know almost nothing. It is very difficult to tell without knowing from actual observation which ponds will be visited by Amblystoma and which will not. It's easy enough to locate ponds they ought to lay in but don't. One of their favorite sites is an old bend of a stream which has been cut off from the main channel so that it no longer has any appreciable current. Nothing, in fact, pleases them more than what geologists call "ox-bows," although their choice is by no means limited to such situations. So far as I have observed the only generalization possible is that a pond where Amblystoma lays is always in or near a woods, although the woods may be very small, in fact surrounded by built-up city streets.

It is not unlikely that the adults always migrate *down* to the ponds in spring. The animals I have seen entering the water have always been coming down from a hillside. But this is only a guess. Certainly if they wander very far during the summer, merely marching straight down hill when they first become active in the spring must often bring them out far from any pond. And even supposing it is true that all Amblystoma on first awakening in the spring walk down hill, this astonishing fact is itself quite unexplained. Once in the proper pond, it would seem probable that the females swim about until they are attracted by some odor given off by the spermatophores. This odor is also probably the stimulus for the females to place the sperm packets up their reproductive tracts.

The eggs themselves are subsequently laid at intervals during a period of ten days to two weeks. They are usually mistaken for a frog's egg, although each one is slightly larger than a frog's egg and of a soft cinnamon brown. The jelly in which each cluster is embedded is considerably stiffer than is the case with frogs and is as clear as the clearest Copenhagen glass.

It is not, however, their beauty but their usefulness and availability which has attracted biologists. Ever since Agassiz made his classic study on turtle eggs (and in fact before) the problem of development, of how a complicated animal arises from a simple egg has been one of the central problems of biology. To-day, in the work of an entire school of biologists, the problem of the origin of the individual occupies the same position that the question of the origin of species once held. Indeed the first problem now seems to be the key to the second and to many other problems.

However that may be, almost all the

modern theories of development have been worked out on the eggs of salamanders because they lack the fetal membranes which surround the embryos of all higher animals, even turtles, and make experimentation extremely difficult. It was for his work on the egg of a salamander that Spemann received a Nobel prize.

So every spring in this country and in many others thousands of salamander eggs are taken into laboratories to be used in a far greater diversity of experiments than Agassiz could ever have imagined. But long before these are concluded, the Amblystoma will have disappeared and the ponds will remain deserted until after a full roll of the seasons, when there will be another good rain and sufficient thaw.

WHY THE SOCIAL SCIENCES LAG BEHIND THE PHYSICAL AND BIOLOGICAL SCIENCES

By JOSEPH MAYER
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We often hear the question raised these days as to why the social sciences continue so backward, while at the same time the physical and biological sciences have moved forward with unprecedented rapidity in the past 100 or 150 years.

Attention is constantly being drawn to the marvelous advances of physics and chemistry that have resulted in the invention of the steamship, railroad and ocean cable, in the application of electrical energy to many practical uses, in the development of gasoline combustion and in the synthetic products growing out of applications of chemical discovery. In geology and biology, also, rapid strides have been made in the past century. But over against these advances there apparently has been little, if any, real progress in an understanding of human relations and in the solution of problems such as war, minority protection, unemployment, maldistribution of wealth and income or depression.

In endeavoring to clarify the reasons for this sharp contrast between rapid progress in one direction and sluggish progress in the other, one may profitably trace the history of science from early Greek times to the present day. A definite sequence of development is indicated, from the most abstract understanding of nature to the more concrete problems which we designate as human or social. Mathematics seems to have been the only science that the ancient Greeks succeeded in establishing on a fairly secure basis, even though certain mathematical developments were left to the later Hindus, as in the so-called Arabic notation and the symbol zero, which developed centuries afterwards. The ancient Greeks attempted to understand other branches of knowledge in addition to mathematics. They assembled considerable materials in the fields of astronomy, physics, geology and biology. But knowledge at the time was so meager in these fields that in most of them the Greeks handed down to their successors about as much misconception as accurate information. Aristotle, the greatest of the ancient Greeks, held back progress, through the misconceptions he fathered, about as much as he cleared the way for further advance in the development of such rigorous techniques as logic and the inductive approach to an understanding of nature.

It was not until after 1600 A. D. that the next important steps in scientific development occurred. Around 1600,

astronomy shook off the misconceptions that had prevented its constructive advance and, with the work of Kepler and Galileo, established the Copernican system which to-day forms its secure basis. Had it not been, however, for some of the mathematical developments of the ancient Greeks, especially those having to do with conic sections, Kepler would not have been able to discover the laws of planetary motion. It should also be noted that the great work of Galileo in astronomy depended to some extent upon the development of the telescope, a product of physics.

Physics and astronomy are, to be sure, very closely related in their fundamental principles. Soon after astronomy was established as a science, Sir Isaac Newton laid the foundations for further advances in mathematics and astronomy and especially in physics. In these developments he was aided considerably by additional important work by Galileo and other scientists. By 1700, physics was well along the road to a discarding of past misconceptions and to a building of that foundation which has made possible the important practical advances of the past two centuries.

Another century passed before chemistry, aided by the development of certain principles in physics found a secure basis for its own establishment as a science, at the hands of such men as Black, Priestley, Cavendish and Lavoisier. By the time of the French and American Revolutions, this branch of knowledge was also on its way to a constructive development. By the third of the next century, enough groundwork had been laid for the extraordinary advances in organic and then in inorganic chemistry that followed.

Until physics and chemistry were well enough along in the development of principles and of such tools as the microscope, the balance and the thermometer, it was impossible for geology and biology to find sufficient root for their modern advance. It was not until 1830 that gross misconceptions regarding geological phenomena were being swept away and that Sir Charles Lyell, in his writings, was laying the foundations for modern geology. And it was not until 1860, or thereabouts, that the three great generalizations were developed which laid securely the foundations of modern biology. These were the discovery of the cell and protoplasm, the discovery of the germ layers and the enunciation of the evolutionary hypothesis. From 1860 onward, we find the gross misconceptions of biology disappearing, and scientific hypotheses regarding life processes, upon which a reliable structure could be erected, taking their place.

It was hardly possible to understand anything clearly about psychology or the things of the mind until that part of biology was far enough advanced which deals with the structure of the sense organs, such as the eye and the ear, with the tracing of the nervous system, and especially with the analysis of the functions of the spinal cord and the brain. These developments did not come until the last half of the nineteenth century. It is not strange, therefore, that modern psychology takes its beginnings from such men as Wundt in Germany, who developed physiological psychology, from Charcot, Janet and Freud in France and elsewhere, who developed the meaning of the subconscious and the important devices of hypnosis and dream analysis, and from William James in the United States, who, toward the end of the century, brought together the various fragments of psychological advance and laid the foundations for modern psychology.

For an understanding of social relations, whether political, economic or more general, it is necessary, first, to have a sound understanding of the environment

in which the human being finds himself, which is the task of most of the sciences we have outlined, and, second, of man himself, that is, of his biological and psychological limitations and potentialities. Such an understanding was impossible until biology and psychology were far enough along the road of modern scientific development. It is only now, in fact, that any satisfactory understanding of social phenomena is becoming possible. Thus it is not peculiar that the social sciences should have lagged behind the physical and the biological sciences, awaiting the day—which is our own day—when sufficient background might be available for constructive advance. There still exists in the social disciplines any number of misconceptions, carried down to us from the past and particularly from the medieval period, which must be swept away before we can make rapid progress in the social studies. With respect to these further tasks, it might be added, I have attempted a somewhat detailed analysis of a ground-clearing nature, in two recent articles, appearing in the July and October issues, 1936, of the journal, *Philosophy of Science.*

We may not even now be ready for this rapid advance in the social studies; but, at any rate, in the light of the history of science, we can at least understand why it is that there is so much uncertainty, hesitation and misunderstanding in contemporary efforts to solve social problems. Only as we reach down into all the sciences that are antecedent and utilize them for the task ahead, can we hope some day to have as clear an understanding in economics and government and sociology as we have long since secured in the physical and in the biological sciences.

TANTALUM CARBIDE:

A SUBSTANCE WITH THE HIGHEST KNOWN MELTING POINT

By PHILIP M. McKENNA
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WHY should a substance with the highest known melting point be of interest to the natural philosopher? First, because extremes are always interesting as testing generalizations drawn from limited ranges and extrapolated to conditions not yet tested. Second, because the various properties of substances are correlated, and the possession of one extreme property may imply other interesting attributes. Third, because our control over experimental conditions is aided in a practical way when we find a new tool or substance with which we may work.

Tantalum carbide has a melting point of 4150° absolute or 3877° C, plus or minus 140°. (It is true that hafnium carbide is reported to have a melting point 10° higher than this, but the scarcity of hafnium and its difficulty of separation from zirconium leaves the immediate domain of highest melting point to tantalum carbide.)

Tantalum carbide has been prepared in crystalline form having metallic golden luster. So prepared, it had a higher density than hitherto reported, namely, 14.48, while previous compounds of tantalum and carbon were reported as only 13.95 to 14.05 density. Strange to say, this new tantalum carbide has a slightly higher carbon content than previously reported for the combination of tantalum and carbon, namely, 6.224 instead of 6.20. This was a surprise, as carbon is a very light element compared

to tantalum. Evidently the carbon in this new form of TaC is packed more closely or in more orderly arrangement.

By x-ray crystallographic analysis it was determined that the crystalline form was similar to that of common salt, NaCl, with alternate atoms of Ta and C in cubic face centered arrangement. A pleasant confirmation of the lattice dimensions, atomic weights and density was obtained by back reflection precision x-ray diffraction methods, for the distance between the Ta atoms was deduced from these x-ray photograms to be 4.445 Ångstrom units. Calculating what the density should be if the unit cube contained four molecules of TaC and unit atom weight 1.6489×10^{-24} grams, the following results are obtained:

$$\frac{4 \times 192.88 \times 1.6489 \times 10^{-24}}{(4.445 \times 10^{-8})^3} = 14.47$$

This was very close to the observed density of 14.48.

Why should TaC have this high melting point, higher than either carbon or tantalum alone? Because it is a compound, rather than a solid solution or eutectic, seems a good answer. Carbon boils at about 3600° C, and tantalum melts at 2850° C, but the compound TaC melts at 3877° C +/− 140°. That the melting point of tantalum carbide is really higher than the vaporization point of carbon has been shown in an interesting experiment reported by Agte and Alterthum.[1] In this experiment tubes of tantalum carbide were fastened between water-cooled electrodes in a sealed glass vessel filled with hydrogen or in other cases with argon-nitrogen mixtures. Inside the tube carbon blocks were placed. By conducting low voltage heavy ampere current through the tantalum carbide tubes they attained high temperatures and the carbon blocks began to vaporize at 3450° C and sublimed onto portions of the glass vessel. Temperatures of 3630° to 3827° C were maintained without destruction of the tubes and with vaporization of the carbon.

Another carbide of a refractory metal, namely, tungsten carbide, has a melting point lower than either the metal tungsten or carbon. Tungsten metal melts at 3370° C, while the carbide WC melts at 2867° C. In this case we have the so-called compound with a melting point lower than either element. In general, the carbides of elements Ti, Zr, Hf, V, Cb and Ta, which are in the fourth and fifth groups of the periodic table, have higher melting points than the metal alone, while carbides of elements of the sixth group, such as chromium, tungsten and molybdenum, have melting points lower than the metal. It may be significant that tantalum carbide has a positive heat of formation, while tungsten and carbon apparently have approximately zero heat of formation.

Columbium carbide also has a very high MP, namely, about 3500° C.

Table I, compiled after Ernst Friederich, is an effort to correlate physical properties with the valence and distance of atoms apart, assuming that forces exist varying inversely as the square of the valence.

It will be observed that the hardnesses and melting points ascend with an increase in the factor

$$\frac{100 \times W^2}{V_a^{2/3}}$$

The exception seems to be vanadium carbide; experience with it seems to show that it breaks up into V_4C_3 and that the compound VC does not persist up to the melting point. This series consists only of compounds having the NaCl type crystalline lattice. While this factor is apparently only an approximate measure of the properties of substances it shows tantalum carbide at the high end of the series, as is its rank in melting point and hardness as far as may be determined.

The mechanics of "hardness' needs definition and clarification. Breakage of

[1] *Zeitschrift für technische Physik,* No. 6, pp. 188 and 189, 1930.

TABLE I

FIGURES OBTAINED BY CONSIDERING THE VALENCE SQUARED DIVIDED BY THE ATOMIC VOLUME TO THE TWO-THIRDS POWER IN A SERIES OF COMPOUNDS SODIUM CHLORIDE TYPE CRYSTALLINE ARRANGEMENT

Compounds[a]	NaCl	AgCl	NaF	PbS	CaO	MgO	TiN	ScN	VN	CbN	TiC	ZrC	HfC	VC	CbC	TaC
Valence	1	1	1	2	2	2	3	3	3	3	4	4	4	4	4	4
Density	2.2	5.56	2.83	7.42	3.37	3.65	5.18	4.46	5.63	8.40	4.25	6.90	12.20	5.36	7.82	14.47
Lattice[a]	5.628	5.54	4.62	5.97	4.79	4.20	4.40	4.44	4.28	4.41	4.60	4.76	....	4.30	4.46	4.445
Atomic vol.	13.53	12.8	7.42	16.1	8.39	5.57	6.17	6.65	5.77	6.42	7.05	7.48	7.81	5.87	6.708	6.67
$100 \times \frac{W^2}{V_A^{2/3}}$[*]	18	19	26	63	97	127	268	255	280	260	435	418	406	491	450	452

[a] These compounds are all of the same crystalline form—NaCl type cubic. The distance a is the number of Angström units between similar kinds of of atoms.
[*] W = valence; V_A = atomic volume = atomic weight/density.

crystals probably occurs at the larger fissures attributed to the mosaic structure, rather than between atoms in a lattice. Crystalline form also governs the way substances break under strain, for if slippage may occur without breakage we have malleability. A more comprehensive knowledge of "hardness" may be increased by a study of this extreme member of the series of substances, tantalum carbide.

How tantalum carbide is already serving as a new tool for man's control over his environment is exemplified in the use of tool materials utilizing its properties of resistance to deformation and wear. At present its greatest use is in a series of hard tool compositions containing from 17 to 80 per cent. of tantalum carbide, together with tungsten and other metals such as nickel and cobalt. Pieces of these hard metal compositions are used as tool points, for lathe tools, boring tools, reamers and drills for cutting metals, particularly hard steels. The use of tantalum carbide has greatly extended the possibilities of engineers in constructing machine parts of harder steels. With steel tools, including those alloys of tungsten and chromium used for tools, the machinable range was regarded as below 300 Brinell. Now steel axle shafts and other articles are machined with ease at hardnesses up to 555 Brinell, providing an increase in tensile strength from 148,000 lbs. per sq. in. to 271,000 lbs. per sq. in. in the finished parts.

Other interesting uses are based upon the resistance of tantalum carbide to corrosion. Nozzles and valves operating under acid conditions are now used in various appliances. Tantalum carbide may be boiled in all acids except a mixture of hydrofluoric and nitric without oxidation or attack.

As the world becomes aware of the properties of high melting point carbides they will be found to extend our control over our environment just as the discovery of the use of iron for tools marked a cultural step from the stone and bronze ages. To the experimentalist, endeavoring to utilize conditions of temperature and pressure to investigate changes in matter, tantalum carbide may provide apparatus which is needed.

Thus we may justify an interest in this unique compound to the scientist, as exemplifying an extreme of a series; to the engineer, as providing a new tool; and to the experimentalist as a new thing to achieve his purposes.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]
WASHINGTON, D. C.

THE WASHINGTON FIELD MUSEUM

Unique among museums in the United States is one in Washington, N. C., which has been developed and is operated in regular, full-scale museum style by the young folks of the town, mostly those of high school age. The Washington Field Museum, as it is called, is a full-fledged member of the American Association of Museums, and its youthful curators spent part of their spring vacation time in visits to its larger sister establishments to learn some new tricks of the craft for their own use.

It all started back in 1923, when a few high school students pooled their amateur collections of butterflies, snakes, etc., in a tent made of sacking. They named their embryo institution "The Bughouse Laboratory."

Instead of dying out presently, as such ventures are apt to do, the Bughouse Laboratory survived. It moved into a backyard kitchen, then into an empty store building. The Bughouse Laboratory became socially "the thing"; membership on its staff was more desirable than a bid to a fraternity.

Successive school generations graduated and grew up, and their younger brothers and sisters took their places. The "founding fathers," still young folks, began to have influence in the community. They secured a plot of land, which has been developed into a neat little park. A lumber company donated building materials, WPA labor was secured, and presently the Bughouse Laboratory moved into its new quarters, and added to its title the more formal style of Washington Field Museum.

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

There is a full-time director, Miss Mary Shelburne, but the rest of the curators are still boys and girls from school. They pursue all branches of research and collecting, with special emphasis on natural history and early Americana. A number of live animals have been donated, so the museum is now in the process of developing a zoo.

TESTING FOR SURFACE ACCURACY

A human hair about 15 feet across. That is what it would be if it were magnified with one of the latest testing devices for automobile parts.

One of the wonders of modern mechanical engineering is the routine measurement of finely finished surfaces so smooth that magnification of the order of 50,000 times is necessary. So exacting have become the demands of modern machine shop practice that the working surfaces of anti-friction bearings, for instance, require great accuracy and smoothness. Surface irregularities less than a hundred thousandth of an inch (10 microinches) are cause for rejection.

A machine that measures so finely with the rapidity necessary in actual production, has been achieved. The profilometer, as it is called, has a tiny point that traces the almost molecular surface irregularities. This varies the current flowing through a magnet and this current is sent through special amplifiers and circuits. Thus, electrically, there is created that high magnification necessary. The magnified replica of the surface desired is the light-written record of the oscillograph into which the current is fed. If a permanent record is desired, a motion picture camera is aimed at the waving light line of the oscillograph.

How far machine shop precision has traveled during the age of power will be realized when it is recalled that Watt, inventor of the steam engine, was elated when he found that Wilkinson's boring mill could machine an engine cylinder true to within the thickness of a shilling. The dawn of precision in machinery came when the system of interchangeable parts was adopted early in the last century. Arms factories in Connecticut pioneered in measuring accurately with gages. With accuracy increased many fold, this in the principle that underlies the machine age of to-day.

PIPED RADIO CIRCUITS

The enormous carrying capacity of the new "piped radio" systems, developed independently at Massachusetts Institute of Technology and the Bell Telephone Laboratory, is still little realized. In this system, it will be recalled, radio waves are sent down pipes, around bends, and so on to their destination.

A hollow pipe two inches in diameter, for example, can transmit a band of radio frequencies amounting to a width of ten billion cycles a second. This sounds complicated but can be better appreciated if one says that it would permit 2,000,000 people to talk with each other (two to a conversation) over the same electrical circuit. This is allowing frequency channels of a band width of 10,000 cycles a second; quite sufficient for ordinary conversation. Citing the work of Dr. Wilmer L. Barrow, of the Massachusetts Institute of Technology, the *Technology Review* contrasts the message-carrying capacity of wires and cables.

An open-wire telegraph line has a band width of 100 cycles per second and permits one message to pass. An open-wire telephone line has a band width of 3,000 cycles and has one message channel. Open-wire carrier telephone lines have a band width of 30,000 cycles and allow four simultaneous messages. An improved circuit plans for 16 messages.

The coaxial cable would permit 120 voice messages or one television message. Television radio bands have a band width of well over 5,000,000 cycles and carry one television message. The "piped" radio method has a band width of 10,000,000,000 cycles. It could carry 1,000,000 telephone conversations or 2,000 television messages over the same circuit. Dr. Barrow has found that the "pipe" need not be continuous and that the radio waves will jump gaps up to one inch in length.

THE STUDY OF HUMAN BONES

Because human bones are made up of mineral salts, medical scientists have borrowed some of the geologist's methods in order to learn more about bone structure. The geologist turns powerful x-rays onto minerals and by a process known as x-ray diffraction, he can see the pattern of the molecules in crystals of a given mineral. Dr. W. D. Armstrong, of the University of Minnesota, has used this same method to determine the pattern of molecules in crystals of calcium, phosphorus and other mineral salts in human bone.

His findings, reported at a recent meeting of physiologists, led to the same conclusions as those of Dr. M. A. Logan, of Harvard University, who studied bones by a chemical method. Dr. Logan started with calcium phosphate and by chemical processes, adding a molecule here, taking off a molecule there and otherwise manipulating the original material, he traced the chemical life process of bone salt. In the end he found a chemical pattern for the arrangement of molecules in bone salt crystals that was the same as that found in Dr. Armstrong's x-ray diffraction patterns.

Using physiological methods for studying the problem, Dr. F. C. McLean, of the University of Chicago, discovered

a means of calcium transportation and mobilization for bone formation. Under the influence of the hormone produced by the four wheat-grain-sized parathyroid glands in the neck, calcium is transported from bone to blood via the bone marrow, where some of the new blood cells are formed.

Bone salts, contrary to general opinion, are not stable and permanent, Dr. J. C. Aub, of Harvard, found. They are constantly being dissolved and shifted to another part of the bone, where they are redeposited as crystals, and then redissolved and moved again. This new knowledge was gained from studies of patients poisoned years ago by radium.

COAL, WATER AND AIR A SOURCE OF MEAT SUPPLY

Germany already enduring economic siege conditions, and apprehensive of the sterner blockade of war, looks increasingly to her chemists to make her internally self-sufficient. Newest among projects that would smack of magic if they were not based on well-determined scientific principles is one to make coal, water and air the ultimate sources of a meat supply.

The key to this biochemical paradox is the yeast cell. Yeast produced in great masses and fed on cheap carbon-containing foods, plus nitrogen-containing mineral salts, will yield about half its dry weight in crude protein, the stuff lean meat is made of. This yeast protein is not suitable for direct human consumption, but it can be fed to livestock and thus transformed into meat and milk.

During the World War, yeast was raised in considerable quantities, on beet-sugar molasses, waste liquor from starch factories and similar low-grade carbohydrate sources. The nitrogen part of their diet was synthesized out of the air.

After the armistice, mass production of yeast feed became unprofitable, due to the competition of imported meat and cattle feeds. However, experiments have continued, with the objective of making yeast production cheaper. Promising materials have been surplus potatoes and sugar made from wood.

Now, according to Dr. K. R. Dietrich, chemist of Berlin-Dahlem, strains of yeast have been isolated that do not need sugar but can thrive perfectly well on such carbon-containing compounds as lactic acid, acetic acid, glycerin and even ethyl alcohol, plus of course the usual ration of nitrogen captured from the air.

But some of these compounds can now be produced from coal and lignite, by new synthetic processes. Hence the prospect that some day German steers may be making beefsteak out of coal, air and water, via the humble yeast cell.

THE SURGEON'S CHIEF JOBS

In these days when so much is heard about gall bladder operations, surgical cures of cancer, gland grafting and plastic surgery, it is interesting to find that setting broken bones, one of the earliest jobs tackled by surgeons, is still one of their most important, numerically speaking.

Setting of fractured bones stands second in order of frequency, coming right after removal of tonsils, it appears from a statistical study by Selwyn D. Collins of the U. S. Public Health Service's National Institute of Health. A report of the study was recently published by the Milbank Memorial Fund. Mr. Collins obtained his figures from a canvass of 8,758 white families living in 130 localities in 18 states of the union. The canvass was conducted between the years 1928 and 1931 and covered 12 consecutive months.

For every 1,000 persons in this group, 65 surgical operations were performed in a single year. This means the total number of operations in this country each year totals close to 1,000,000. Of these, removal of tonsils constitutes

nearly one third. Setting of broken bones and other operations in connection with injuries take second place and third place respectively and together account for one fifth of all operations. Operations on female organs of reproduction are fourth in order of frequency and removal of the appendix came fifth.

Slightly more operations are performed on women than men. Setting broken bones and other operations in connection with injury, hernia and sinus operations are more frequent in men. Appendectomy, gallbladder, cancer and thyroid operations are more frequent in women. As might perhaps be expected, the frequency of operations increases with income. There is some difference, too, in types of operations according to income. You have to be up in the higher brackets, it appears, before removal of tumors and ear and mastoid operations are undertaken frequently.

A SIXTEENTH CENTURY REPORT OF ASTHMA

The idea that a man can get asthma from sleeping on a feather pillow is still a new idea to many laymen. Actually, a case of asthma was attributed to feathers and cured by removing the feather bed as long ago as 1575. In that year Jerome Cardan, a great physician of Padua, was called to Edinburgh to see the Archbishop who suffered from asthma. The Paduan physician probably had no idea of allergy, or hypersensitiveness to feathers, such as physicians have to-day. Certainly he was not able to make skin tests of his distinguished patient. But Cardan was able, as good physicians have always been, to observe and study his patient carefully and to make logical deductions from his observations. Cardan finally advised the Archbishop to give up certain articles of his diet and to get rid of his feather bed. Relief of the asthma promptly followed.

The story is retold by Louise Stedman and Merle Ford in a report to the *Journal of Home Economics*. The report concerns itself with textiles which, like feathers, plant pollens and foods, can cause asthma, hay fever, migraine headaches, hives or other forms of allergy.

Cotton, silk, wool, kapok, rayon, leather and rubber can all cause allergic symptoms in hypersensitive persons, but of the fabrics silk seems to cause most trouble. Cottonseed and flaxseed or linseed are troublesome in cases where cotton or linen fabrics may not be. Kapok may not cause symptoms at first but when the fibers become dry and brittle they cause a fine dust which may be troublesome. Dyes used in fabrics are often allergy-causing in themselves. Rayon waste is said to be one of the safest nonallergic upholstery stuffing materials. Smooth fabrics can often be tolerated when a rough weave of the same material causes trouble.

SOIL EROSION

Malthus' ghost has returned to haunt us, in a new guise.

During the nineteenth century, the principles of Malthus, first set forth in his famous essay on population in 1798, were among the dominant ideas in political and social thinking. Briefly, Malthus took the gloomy view that human population always tended to increase faster than its food supply, and that misery and want and war were the inevitable consequences.

Malthus left out of consideration (for the good reason that he did not know anything about them) a number of factors that have operated at least in part to prevent realization of his pessimistic prophecy. Improvement of crop plants and food animals, invention of more efficient cultivation methods, and better means of keeping and marketing food have done much to increase the food supply. Later marriage, wider use of con-

traception and possibly other factors have slowed down population increase.

But just as we are congratulating ourselves on the laying of the Malthusian ghost, up it pops again, out of the gullies of eroded and abandoned farm lands. Professor Paul Sears, author of "Deserts on the March," expresses it as a general principle: "In the development of any civilization, the total area of cultivable land tends constantly to diminish."

Professor Sears has pointed out the working of this principle in all the world's dead and dying cultures: Syria and Chaldea, Rome and China—and our own. Not only for necessary bread but for swollen profits, men strip the forest, pasture goats on the hills, tear the banquet-cloth from earth's table with over-eager plows. Ruin has always followed. Ruin threatens now.

Yet there is time. Just as we eased the pressure of the older Malthusianism with better crops better cultivated, so now we can restore forests and grasslands, stop gullies, plow more sensibly. It will cost money, require more effort. But the alternative choice is decline and ultimate death.

A STUDY OF SLIPPERY ROADS

Using some of the fingerprint tricks of Scotland Yard, the Department of Scientific and Industrial Research of Great Britain is now studying slippery roads by taking fingerprints of motor car tires.

As reported in *Industrial and Engineering Chemistry,* published by the American Chemical Society in Washington, D. C., the road under study is coated with an ink and a perfectly smooth tire rolled over it. The tire is then transferred to white paper and an exact record of the texture of road surface, over which the tire has rolled, is obtained.

Slippery roads have been found to be those in which there is a high ratio between the total area of contact between tire and road and the number of isolated points of contact. The latter, isolated areas, must be surrounded by channels deep enough so that the water on the road can escape as the tire passes over. If the channels are too small the individual areas merge and the surface behaves like a smooth one. The requirements for non-skid tires are similar. On very slippery roads studies show that the tire makes contact with the pavement over nearly all its surface of contact while the number of individual contacts is small. Good roads, low in skid values, were found to be those yielding prints that disclosed a lesser area of total contact and many more individual points of contact. A "sandpaper" surfaced road, with its many tiny and almost imperceptible points of irregularity, is typical of a highway low in slipping characteristics. Not only are different road surfaces being studied, but tests are also underway to study the skidding characteristics of the same roads at different times of the year.

EXTERMINATION OF THE WHITE-FRINGED BEETLE

War's grimmest machinery—flame-throwers, poisonous chemicals, even the "scorched earth" tactics made famous in the Chinese conflict—will be brought into concentrated operation in the South this spring, and all against an enemy only half an inch long. Major fighting will begin late in June, when the white-fringed beetle, an invader from South America, emerges from its underground winter quarters.

The white-fringed beetle appeared in the United States for the first time only last summer, and its distribution is still limited to about ten scattered small areas near the Gulf of Mexico, from the western end of the Florida panhandle to a point near New Orleans. It is the hope of federal and state entomologists that

they can wipe it out entirely by drastic measures, as they did the Mediterranean fruit fly in Florida a decade ago.

At present the insects are safe from human attack. They are still grubs, feeding on the roots of plants. But in early summer they will appear above ground, to migrate, mate, and lay eggs. Then is the time for attack. Where the beetles are thickest, the earth will be swept clean of all vegetation, sprayed with oil not only to kill the insects but to keep plants from growing. With no green stuff to eat, the beetles will starve and of course produce no offspring. These thickly infested spots will also be circumvallated with trenches to blockade the enemy within, and flame throwers will move back and forth, spreading fiery death.

Where there are fewer of the beetles, crops may be grown; farmers are advised to plant corn, which the beetles do not like, rather than such southern crops as sweet potatoes and velvet beans, which they find more appetizing. Cotton is also recommended, for the beetles will gather on the leaves, where they can be reached with sprays or dustings of calcium arsenate which has been found effectively lethal to this pest.

PLANT SOCIOLOGY

Diverse social groups that just don't get along with each other often base their mutual dislike on things scarcely tangible yet very potent, like alien modes of speech or unaccustomed cooking odors. Dinty Moore's redolent kettle of corned beef and cabbage is more than a comic-section joke; it is the boundary marker between hostile cultural states.

Plants no less than human beings often develop feuds or friendships from much the same sort of subtle chemical causes. Dr. Gerhard Madaus, a German physician, has made a special study of some phases of this "chemical plant sociology," which started with his experimental plantings of drug plants but has been extended to take in the likes and dislikes of several varieties of crop plants as well.

Dr. Madaus calls attention first to the often-observed fact that the plant growth in certain types of evergreen forest is sparse, and poor in number of species. Most plants can not tolerate the acid compounds from the trees' needles. He also cites experiments by American as well as German plant physiologists, wherein the mere presence of odorous plant substances, such as the scent of apples, oil of bergamot, or turpentine, accelerate seedling growth in light but hinder it in darkness.

Of greater economic significance, possibly, are his experiments with paired species grown together and separately. Thus, he found that corn and wheat planted in the same pot produced a more rapid growth of wheat. Bean seeds in water that had bathed the roots of oats sprouted more quickly than did similar seeds in water from corn roots. Grapevines with cypress spurge (a common vineyard weed) growing close to their roots failed to set fruit. In some instances it is known that root secretions are responsible for these mutual effects, and it seems quite likely that similar substances act in like manner in other cases.

RUBBER CONTENT OF DESERT MILKWEED

Edison's experiments with goldenrod as a possible source for rubber were a nine-weeks'-wonder in their time. But Edison died, and his successors have apparently done nothing further with goldenrod rubber. At any rate, they have said nothing about it.

Less conspicuous but more persistent has been the work of botanists of the U. S. Department of Agriculture. Always before them is the hope of finding within the boundaries of the United

States some source of rubber that can be worked if a world war or other emergency cuts off the normal supply from across the Pacific.

R. E. Beckett, R. S. Stitt, and E. N. Duncan have recently reported analyses of a species of desert milkweed that show its leaves to contain as high as 13 per cent. of rubber, dry weight basis. They have grown the plant from seeds at the U. S. Acclimatization Garden near Bard, Calif., and find that strains of the weed with hereditary tendency to high rubber content can be isolated.

The three botanists describe the milkweed as growing in solid clumps of ten or twenty stalks, from three or four feet to six feet high. It is native only in the drier parts of the Southwest and adjacent parts of Mexico. They found it growing only in gravelly stream beds that are dry most of the time, and in borrow-pits along roadsides.

Harvesting the milkweed, even for experimental purposes, had to be done during a comparatively limited time, because it has the habit, common among desert plants, of losing its leaves soon after maturity. However, the dried plants could be stored for many months without noticeable loss of rubber content.

If it should ever become economically desirable or necessary to cultivate the plant, milkweed farms should not be difficult to establish, for seeds are abundantly produced and germinate readily.

DECLINE OF THE WHALING INDUSTRY

The sad state of a once-glorious maritime industry—whaling—is typified by the number of vessels in the whaling fleet accredited to the United States. Back in 1846 America had 735 vessels at sea catching whales, says Commissioner Frank T. Bell, U. S. Bureau of Fisheries. To-day the nation has—well take a guess for yourself before you read the next line.

The answer is three factory ships and 31 small killer boats! Two shore stations also still exist.

In 1846 whaling employed 40,000 people of American nationality, had an investment of $40,000,000 in its ships and other equipment and made an annual catch valued at $8,000,000. To-day America's small whaling fleet produces products having a value about a third as great as in 1846, or approximately $2,600,000. The return on the investment is about as good as it was back in the peak period of American whaling.

Whaling, which now interests the world more as a conservation effort than as a leading industry, has gone through three distinct periods, says Mr. Bell. From the time the first Basques started whaling in the 12th century until 1868, harpoons were thrown by hand in a sort of personal hand-to-hand combat with the giant sea-going mammals. In 1868 the invention of the harpoon gun speeded the kill and enabled greater efficiency in hauling the whales to the shore processing stations. The third, or modern, era has been the establishment of factory ships which process the whales at sea, far from their home ports or shore stations.

One whale yields as much meat as 100 cattle and in Japan is sold for food, to people too poor to buy beef. A contrast between the old and new in whaling is typified by modern processing. A blue whale which in the early days was worth only $40 to $50 for its blubber is now worth $4,000 in Japan because of its many by-products.

LABORATORY TESTS OF WOOD PRESERVATIVES

By JOHN LEUTRITZ

BELL TELEPHONE LABORATORIES, NEW YORK

EVERY year approximately a half million new poles of southern yellow pine are used in the Bell System either for replacements or for new lines. If these poles were left unprotected from the action of lower forms of plant and animal life—fungi and termites—the economic loss would be serious. Their life can be greatly extended, however, by treating the poles with a suitable preservative. There are many preservatives on the market, and new ones are being offered from time to time to pole manufacturers, so that techniques for evaluating them must be available. Outdoor exposure tests of wood preservatives are usually slow and expensive, and it is necessary to supplement such studies with quick and inexpensive laboratory methods.

Recent experimentation has evolved an improved laboratory test which is simple and adaptable and yet gives reproducible results which are consistent with field trials of the same material. Briefly, it involves the impregnation of small pieces or blocks of wood with the preservative to be tested, and their exposure in separate glass jars to the action of different fungi. After several weeks, the preservative's effectiveness is rated by the amount and density of the fungus growth, the decrease of weight of the samples and their loss of mechanical strength.

The blocks used in testing preservatives are from the sapwood of southern yellow pine, of uniform density and rate of growth, cut usually into cubes, two centimeters on a side. Since the moisture content of the wood varies over a wide range, depending on the relative atmospheric humidity to which it has been exposed, the blocks have to be brought to a definite humidity content before each weighing at the various stages of the test. For this purpose there is used an ordinary bacteriological incubator fitted with slow-moving fans and pans of saturated solution of sodium chloride. It maintains a relative humidity of 76 per cent. at 30° C. which gives the blocks a moisture content of about 14.1 per cent. when compared with the oven-dry state.

The procedure usually followed in studying a new preservative is to inject blocks conditioned as above, with a solution of the preservative. The pieces are weighed immediately after impregnation to determine the amount of preservative injected, and after evaporation of the solvent they are reweighed under the standard conditions, referred to above, to serve as a further check on their actual content of preservative. This is of extreme importance in working with volatile preservatives.

Each impregnated block is supported by a thin slab of untreated wood on the top of a small wide-mouthed bottle which contains water. The slab also acts as a secondary food source for the growth of the fungus. Wooden surgical-applicators, cut in half, are used to anchor the wood and to serve as wicks for conducting water through the test pieces. For protection the small bottles are wrapped in cotton and placed in larger bottles with screw caps. The complete set-up is sterilized for fifteen minutes at fifteen pounds pressure and then cooled to room temperature. Then a small section, cut from

INCUBATION ROOM WHERE THE BOTTLES ARE STORED DURING THE 24-WEEK TEST PERIOD AT A CONSTANT TEMPERATURE OF 26° C.

a pure culture of a wood-destroying fungus, is placed on the untreated slab of wood opposite the test specimen. The bottles are kept in an incubation room, and observed every four weeks for the extent of the fungus growth. After an exposure to the fungus of about 24 weeks, the blocks are again brought to equilibrium in the humidity chamber and weighed. The loss in weight so determined serves as one of the indications of the efficacy of the preservative.

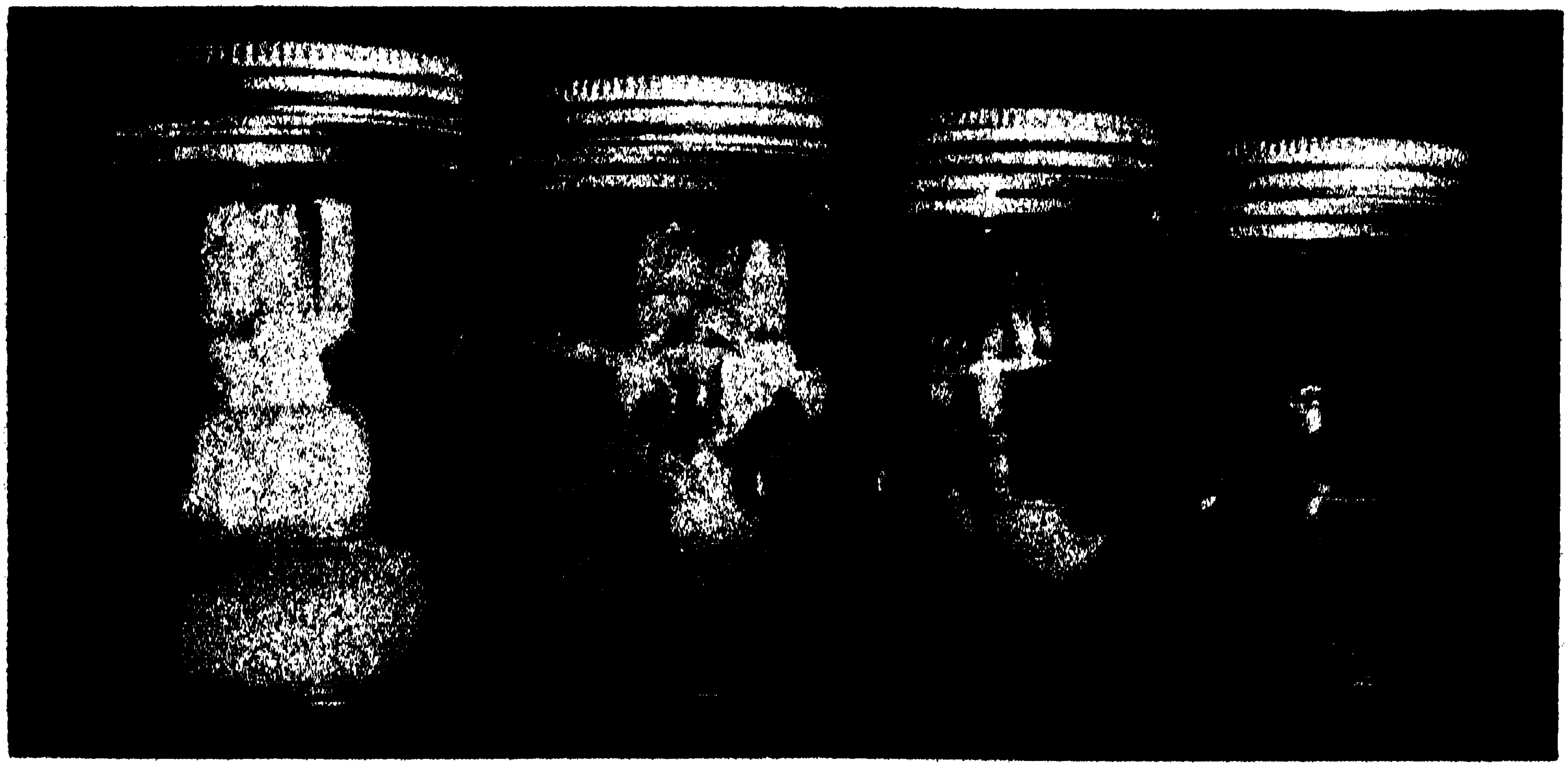
At the present time some six hundred species of fungi are known to attack wood, and since all can not be used in each test for preservatives care must be exercised to select representative fungi. Previous experience has shown that in addition to extreme variability in virulence to different species of wood the fungi display marked idiosyncrasies towards various preservatives. On the basis of these two factors many of the fungi chosen have been found in southern pine telephone poles which had failed in service.

One of these, the fungus, *Lentinus lepideus,* has been repeatedly found on

COMPONENT PARTS OF THE APPARATUS USED FOR THE WOOD-BLOCK ASSAY OF PRESERVATIVE MATERIALS.

test specimens in the laboratories' test "garden" at Gulfport, Miss., and on poles in widely separated areas in the United States. It possesses a marked resistance to certain organic preservatives, and is mentioned by several investigators as being of wide-spread economic importance in the decay of building and structural timbers. Another fungus, *Lenzites trabea,* also exerts a strong resistance to organic preservatives, but since the type of decay produced is unique in that it takes place primarily at the surface, this fungus is also included in most tests. The resistance of *Fomes roseus* varies greatly, but this flat-growing and innocent looking fungus masks an occasional virulence which makes it an essential member of every test.

Another organism included in all tests has not been identified as yet, despite attempts by several mycological authorities. It masquerades under the designation U–10. Isolated a few years ago from



TEST OF A PRESERVATIVE WITH THE WOOD-BLOCK METHOD SHOWING THE EFFECT OF INCREASING CONCENTRATION ON THE GROWTH OF THE TEST FUNGUS *Lenzites trabea*. GROWTH RATINGS FROM LEFT TO RIGHT ARE 4–4, 4–3, 3–2, 0–0.

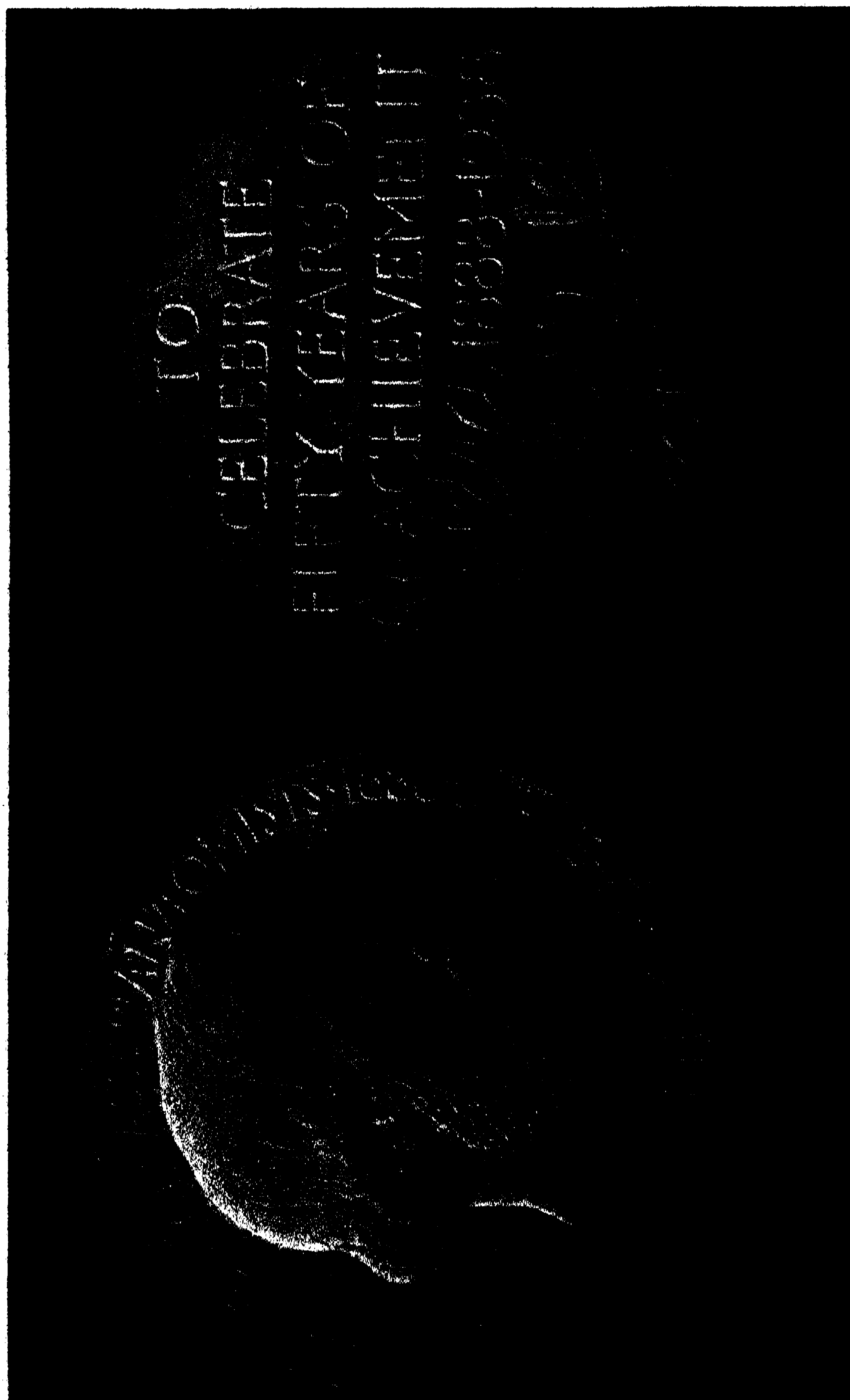
a decayed pine telephone pole, it is especially valuable when a quick indication of the value of a new preservative is needed, as it is capable of producing a very appreciable weight loss in about three months. When preservatives of the inorganic type are under consideration common dry-rot fungi are used because of their specific resistance to this particular class of compounds. From time to time other wood-destroying organisms have supplemented those in regular use.

To aid in interpreting the results of tests on the efficacy of a preservative, untreated controls are also exposed to the different test fungi; and treated controls are put through the entire test cycle without inoculation. These controls are valuable indicators of the nature of the preservative from the standpoint of solubility, volatility and chemical stability; and particularly of the strength lost by the exposed blocks.

Three criteria are available as measures of the value of a preservative. First there is the growth rating which is made every four weeks with reference to the untreated norm. This rating is designated by a pair of numbers, the first of which indicates the extent of the test block covered with the fungus, and the second the intensity and vigor of the growth. Based on 4 as the maximum, 2–4 would mean that the block was partly covered with normal growth and 4–2 wholly covered with sparse growth. A second measure is the weight loss computed from the equilibrium weights before and after exposure to the fungus, with corrections for leaching, volatility or other causes as manifested in the uninoculated but treated test-blocks. The third basis for judging the merits of the preservative is the dissection or strength rating determined by breaking the blocks in small pieces and comparing them with the uninoculated controls treated in a similar manner.

GROWTH ON UNTREATED SOUTHERN PINE SAPWOOD OF THE FOUR ORGANISMS USED NORMALLY IN EVERY TEST. THE FUNGI FROM LEFT TO RIGHT ARE *Lenzites trabea*, *Lentinus lepideus*, *Fomes roseus*, AND AN UNIDENTIFIED SPECIES (U-10) ISOLATED FROM A SOUTHERN PINE POLE WHICH FAILED IN SERVICE. THE SPECIMENS WERE REMOVED FROM THE LARGE BOTTLES FOR PHOTOGRAPHING.

This modification of previous wood-block test methods is no doubt capable of still further development, but several years' experience with it has provided case histories for many preservatives which show a gratifying correlation between results of this accelerated and inexpensive laboratory test and of the slower and more expensive field trials. The severity of the method may in some cases be criticized, but this very severity is essential in the elimination of the poor and mediocre materials unworthy of further study.



THE LEIDY MEDAL OF THE AMERICAN ASSOCIATION OF ANATOMISTS

THE PROGRESS OF SCIENCE

THE ANATOMISTS' ANNIVERSARY MEDAL

Fifty years ago a group of men interested in anatomy met in Washington, D. C., and founded the American Association of Anatomists. Joseph Leidy, professor of anatomy at the University of Pennsylvania, was chosen president. This year the association celebrated the fiftieth anniversary of its founding, at the annual meeting held at the University of Pittsburgh from April 14 to 16. In connection with the celebration, portrait medals of Leidy were struck, as shown in the accompanying photographs. The face of the medal shows in bold relief a profile view of the head of Professor Leidy, and around the edge is the inscription—Joseph Leidy, 1823–91, 1st president, American Association of Anatomists, 1888–91. On the back in island relief are the words "To celebrate fifty years of achievement," and beneath is a spray of laurel. The medals are of bronze, two and a half inches in diameter.

The designs for the medal were made by Dr. R. Tait McKenzie, who from 1896 to 1904 was demonstrator of anatomy at McGill University, and during that period was a member of the American Association of Anatomists. In 1904 Dr. McKenzie became professor of physical education at Pennsylvania. He then divided his time between his professional duties and sculpture, and in the latter field he won renown for his statues of athletes in action and his war memorials. The association was especially fortunate in having one of its former members also a distinguished sculptor, who could do justice to the subject. Dr. McKenzie took up the idea with enthusiasm. As a basis for Leidy's head he used a portrait by Daniel Huntington, painted in middle life, and a Gutekunst photograph, taken at a later period. These he has combined in a harmonious way to produce a head of great dignity and power.

The suggestion of striking a medal bearing the likeness of Professor Leidy came from Professor Frederic T. Lewis, president of the association, and was at once accepted as befitting the occasion. A committee was formed in Philadelphia to arrange for the medal. The committee consisted of Professor Charles W. Burr, a former student and great admirer of Leidy, Henry H. Donaldson and William H. F. Addison. To the committee were later added John C. Donaldson, of the University of Pittsburgh, and Edmond J. Farris, of the Wistar Institute of Anatomy. The committee suffered a great loss by the death of Professor Henry H. Donaldson, who died in January of this year, and recently all have been shocked by the death of Dr. McKenzie. The Leidy medal is, perhaps, the last work that he completed. Undoubtedly it will be more highly prized as the years pass.

Leidy is everywhere recognized as one of America's foremost scientists, and his selection as first president was of great value to the young society. Franklin P. Mall, in his presidential address to the association in December, 1906, said of Leidy: "The greatest of this brilliant group was Leidy, in fact he was the greatest teacher of anatomy to medical students this country has ever seen. His ideals were of the highest and his scientific discoveries were numerous and accurate, contributing much to comparative anatomy and zoology. The good influence he exerted upon the various institutions in Philadelphia has been extended over the nation through this association, of which he was one of the founders."

Professor George A. Piersol, Leidy's successor in the chair of anatomy, had the greatest admiration for Leidy's textbook, "An Elementary Treatise on

Human Anatomy" (1861) and considered it the clearest and most straightforward presentation of the subject possible for the beginning student. Leidy also edited an American edition of Quain's "Anatomy," which was published in 1849. Leidy's connection with the teaching of anatomy began at his graduation in 1844, when he became an assistant in the dissecting room. The next year he was appointed prosector to Professor Horner, and in 1854 succeeded him as professor of anatomy.

"He knew how to use his anatomical opportunities," declared Charles Sedgwick Minot, who admired him, "a Philadelphian by his birth, by his career, and by his death, and no citizen of this metropolis has more deserved public honor than he." Yet his interests were unconfined by any narrow discipline. He searched all sorts of animals, finding material for 597 listed publications, among them "classics of American science." Fundamental studies in vertebrate paleontology, the splendid monograph on rhizopods, the discovery of encysted trichina in pork, the transplantation of cancer cells to the frog, and researches on the comparative histology of the liver and the intimate structure of cartilage in 1848 and 1849, are among those readily recalled. Clear vision, perfect modesty, noble and unflagging devotion to science are qualities to commemorate. These are Leidy's traits, which the sculptor has admirably portrayed in this notable anniversary medal.

WILLIAM H. F. ADDISON
UNIVERSITY OF PENNSYLVANIA

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE seventy-fifth annual meeting of the National Academy of Sciences was held on April 25, 26 and 27, 1938, at the academy building on Constitution Avenue in Washington, with a hundred and twenty-four members in attendance. The scientific sessions were unusually interesting; thirty-two papers were read; although these were of necessity somewhat technical in character, each speaker made a sincere effort to present the general results of his research work and to emphasize their significance rather than to discuss details understandable only to the specialist in that field. Experience has proved that it is not an easy task to prepare a paper for presentation before the general scientific audience of the academy. The excellence of the papers given at the recent sessions showed clearly that this difficulty was realized.

The distribution of the papers among the different fields of science was: astronomy 3, mathematics 4, physics 8, chemistry 2, geology 1, geography 1, paleontology 1, biophysics 5, biology 1, botany 1, physiology 1, pathology 1, psychology 2 and anthropology 1. Twenty-four papers were given by members of the academy and eight by scientists introduced by members. The Monday evening public lecture was delivered by Dr. James Ewing, of Memorial Hospital in New York City, on the subject "The Public and the Cancer Problem." His illuminating and authoritative address on the present status of cancer research and on the relation of the public to it was closely followed and greatly appreciated by the audience eager to learn of the many factors that enter into this difficult problem.

The large number of reports from the field of physics indicated the continued interest in this fruitful branch of science. Dr. R. W. Wood reported upon new large diffraction gratings, ruled on aluminized pyrex blanks, by which 75 per cent. of the incident light of the visible spectrum is concentrated in the second order spectrum; by another grating, 85 per cent. of yellow light is concentrated in the first order spectrum. Drs. W. W. Coblentz and R. Stair described a new method that utilizes unmanned balloons for exploring

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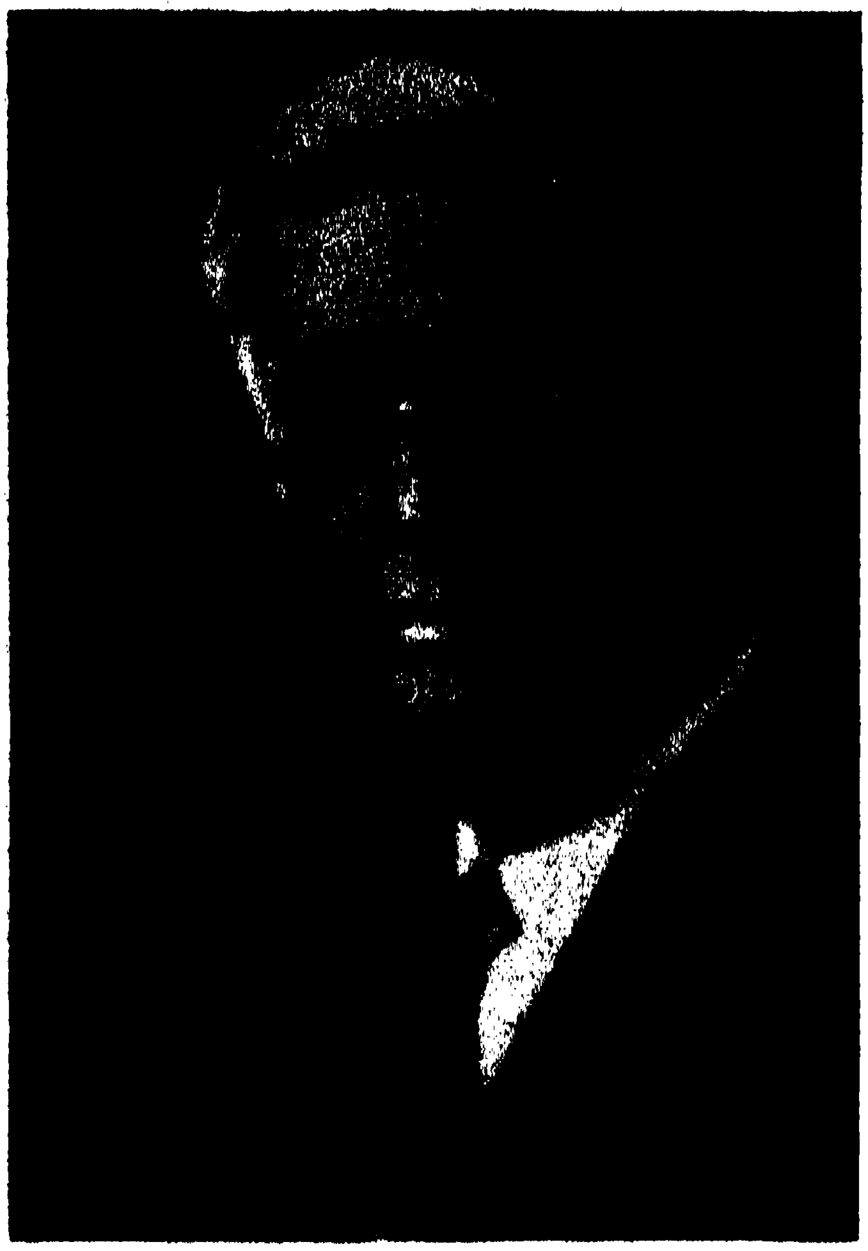

DR. G. W. STEWART
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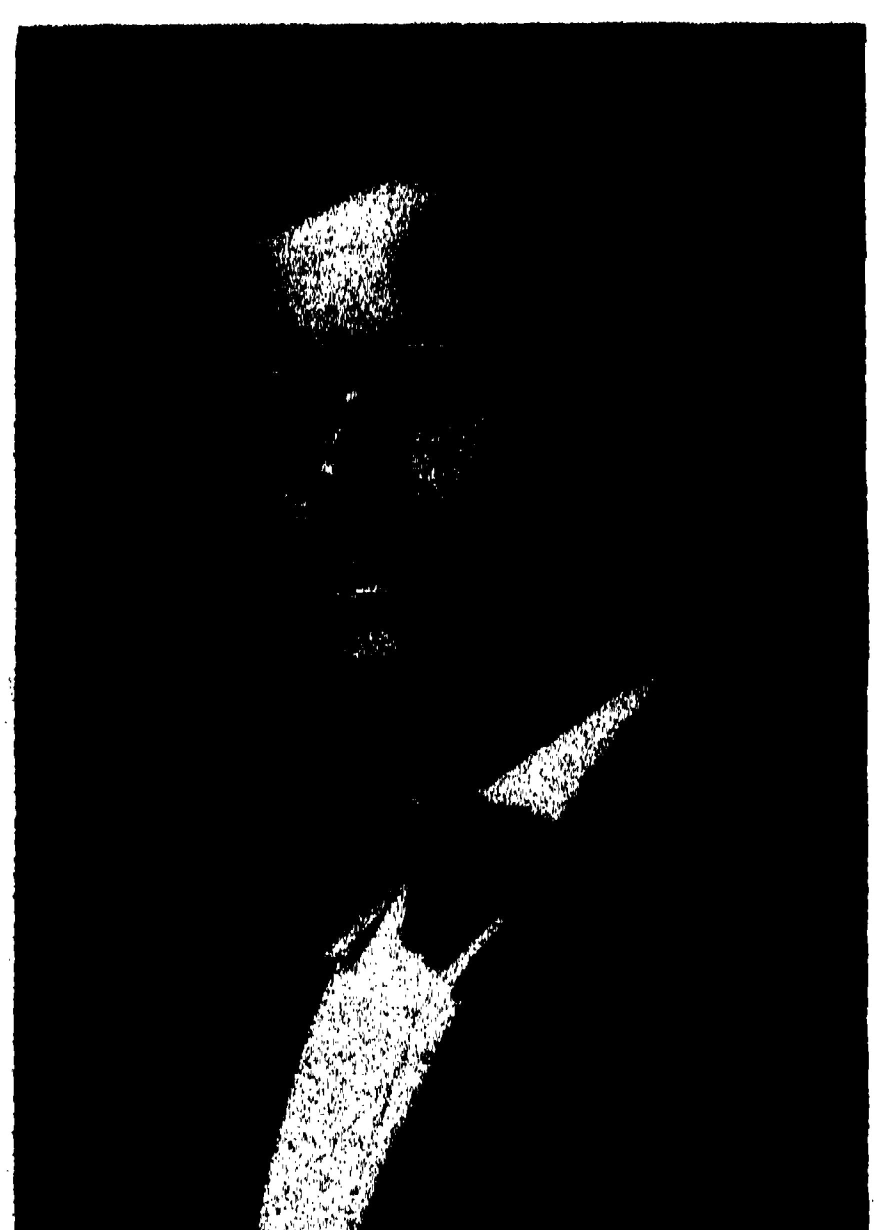
DR. CARL S. MARVEL
PROFESSOR OF ORGANIC CHEMISTRY, UNIVERSITY OF ILLINOIS.

DR. WALTER H. BUCHER
PROFESSOR OF GEOLOGY, UNIVERSITY OF CINCINNATI.

DR. WORTH H. RODEBUSH
PROFESSOR OF PHYSICAL CHEMISTRY, UNIVERSITY OF ILLINOIS.



DR. THEOPHILUS S. PAINTER
PROFESSOR OF ZOOLOGY, UNIVERSITY OF TEXAS.

radiometrically the ultra-violet solar intensities in the stratosphere, thereby obtaining information on the distribution of ozone in the atmosphere to a height of 19 kilometers. Drs. I. S. Bowen, R. A. Millikan and H. V. Neher presented new evidence on the nature and origin of incoming cosmic rays. Dr. H. E. Ives reported upon the results of an experimental study of the rate of a moving atomic clock as furnished by the Doppler effect in canal rays whose velocities can be accurately controlled by use of the Dempster canal-ray tube. In the tube a small concave mirror was inserted so that the end-on observation gave, on one plate in the spectrograph, the displaced spectral lines due to motion toward and away from the spectrograph slit. On the assumption of a stagnant ether, this experiment establishes the physical reality of the Larmor-Lorentz variation of clock rate and the Fitzgerald contraction. Dr. E. Kasner outlined a new method of approach to the geometry of motions and whirls. Drs. O. L. Inman and A. F. Blakeslee described the absorption spectrum of a new type of chlorophyll resulting from a recessive palemutation in the jimson weed (*Datura stramonium*). Drs. H. C. Urey, H. G. Thode and G. E. Gorhan reported upon a new method for the concentration of isotopes of nitrogen and sulfur by chemical means. Drs. R. D. Evans and R. S. Harris described the metabolic effects of ingested radium in rats; this leads ultimately to the production of osteogenic sarcoma. Drs. W. J. V. Osterhout and J. W. Murray described experiments on the movement of water from concentrated to dilute solutions through liquid membranes, a new phenomenon difficult to explain. Dr. H. Fletcher reviewed experiments on the relation of the intensity per cycle of acoustical noise to the intensity of a pure tone of given frequency and just perceptible against the background of noise; he also showed how it is possible, from measurements of this ratio

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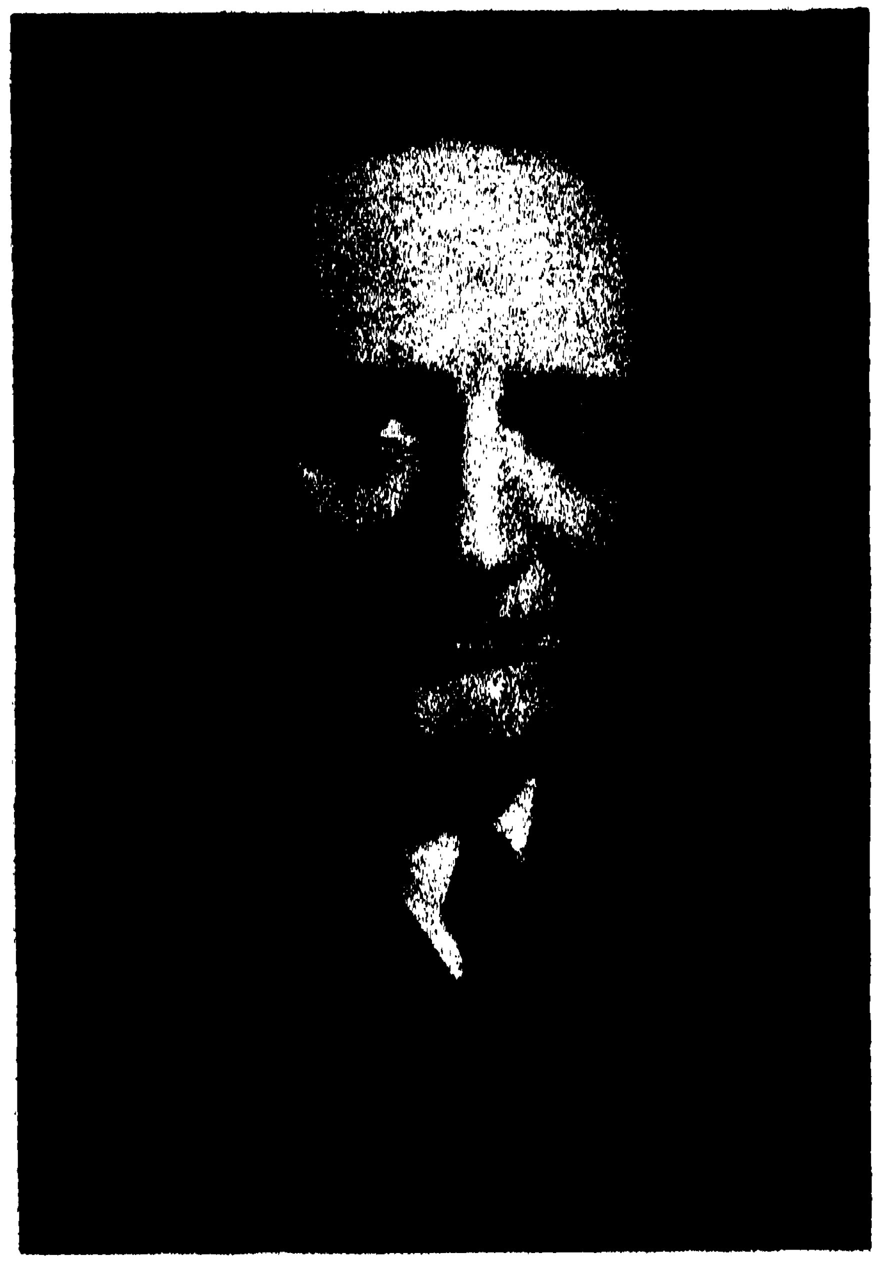


DR. L. L. THURSTONE
PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF CHICAGO.

with change in frequency, to compute the relation between the frequency of the tone and its position of maximum stimulation along the basilar membrane. Dr. W. B. Scott presented the results of studies on members of the camel family existent in North America and nowhere else during the Tertiary period. Toward the end of this period they migrated to South America and to Asia and are no longer found wild in North America.

In his address before the academy at its annual dinner President Lillie alluded in detail to the fiftieth anniversary of the academy in 1913 at which a number of remarkable addresses were given by scientists and high government officials from this country and abroad. He referred briefly to the activities of the academy during the world war as scientific adviser to the government, to the organization of the National Research Council by the academy in 1916 and to its major activities during the past 19 years since the war. He mentioned with special pleasure the Pilgrim Trust Lectureships initiated by the Royal Society and recently established through agreement between the Royal Society of London and the National Academy of Sciences, whereby for a period of six years a Pilgrim Trust lecturer is to be chosen annually. The first lecturer is to be an American scientist appointed by the Royal Society to give a lecture before the Royal Society; the second lecturer is to be a British scientist appointed by the academy to give a lecture the following year before the Academy in Washington. The Royal Society has appointed Dr. Irving Langmuir, member of the academy, to give the first Pilgrim Trust Lecture in December of this year in London.

Two gold medals, awarded by the academy on April 28, 1937, were presented at the annual dinner.

The Agassiz Medal for oceanography, awarded to Edgar Johnson Allen, director emeritus of the Plymouth Laboratory of the Marine Biological Association of

the United Kingdom, Plymouth, England, "in recognition of his personal researches on marine biology and of the great influence which he has exerted on the study of marine organisms in their relation to the marine environment." The presentation address was made by Dr. E. G. Conklin, member of the committee that made the award. The medal was received, on behalf of Dr. Allen by Mr. Leander McCormick-Goodhart of the British Embassy for transmission to Dr. Allen through diplomatic channels.

The Public Welfare medal from the Marcellus Hartley Fund was awarded to Willis Rodney Whitney, of the General Electric Company research laboratories, "in recognition of his outstanding work in the fundamentals of scientific research for the public good." The presentation address was made by Dr. A. W. Hull, chairman of the committee that recommended the award.

At the business meeting held on Wednesday, April 27, the following officers and members were elected:

New members of the council:
- F. K. Richtmyer, Cornell University
- E. D. Merrill, Arnold Arboretum, Harvard University

New foreign associates of the academy:
- Alfred Fowler, professor of astrophysics, University of London
- Pierre Janet, professor of psychology, Collège de France
- S. P. L. Sørensen, director of the chemical division of the Carlsberg Laboratory, Copenhagen
- D. M. S. Watson, Jodrell professor of zoology and comparative anatomy, University College, London

New members of the academy:
- Carl David Anderson, California Institute of Technology
- Walter Hermann Bucher, University of Cincinnati
- Edward Adelberg Doisy, St. Louis University, Missouri
- John Adam Fleming, Department of Terrestrial Magnetism, Carnegie Institution of Washington
- Theodore von Kármán, California Institute of Technology
- Warren Kendall Lewis, Massachusetts Institute of Technology
- William deBerniere MacNider, University of North Carolina
- Carl Shipp Marvel, University of Illinois
- Theophilus Shickel Painter, University of Texas
- Worth Huff Rodebush, University of Illinois
- Lewis John Stadler, University of Missouri
- George Walter Stewart, University of Iowa
- Marshall Harvey Stone, Harvard University
- Louis Leon Thurstone, University of Chicago
- Simeon Burt Wolbach, Harvard Medical School

The present membership of the academy is 303, with a membership limit of 350; the number of foreign associates is 40 with a limit of 50.

The autumn meeting will be held this year on October 24, 25 and 26 at the University of North Carolina.

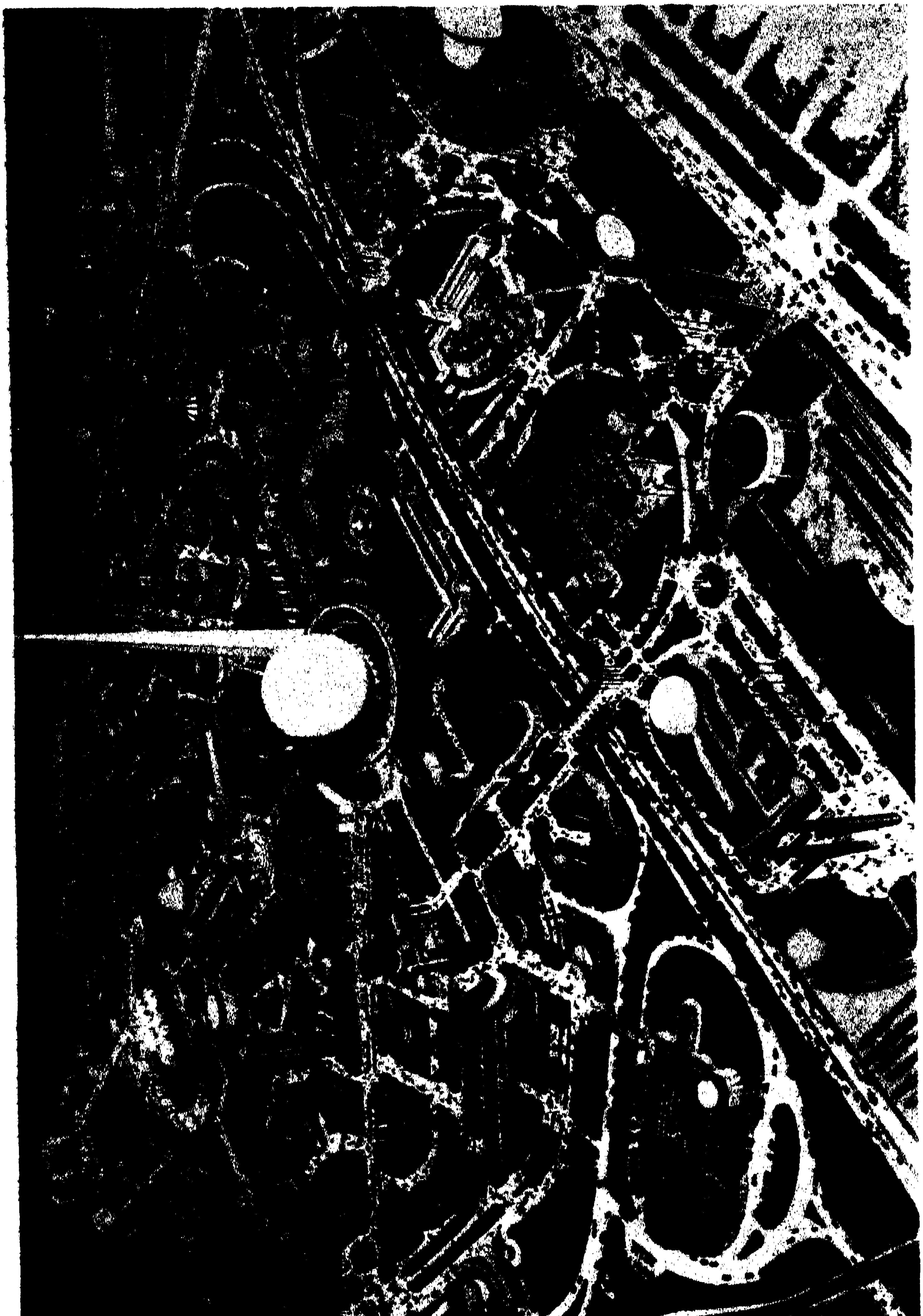
F. E. WRIGHT,
Home Secretary.

SCIENCE AND THE NEW YORK WORLD'S FAIR

"To tell the whole story of modern scientific research instead of a single chapter—as far as practical, to add a working, scientific display to every major exhibit."

This was the difficult ideal set for the New York World's Fair 1939 by Grover A. Whalen, president of the Fair Corporation. And it is an ideal that will come amazingly close to complete realization. Instead of divorcing science from life and isolating it in a separate hall, the exposition will attempt to show the relationship of science to the industries and occupations of daily existence by which men gain their bread and butter.

To carry out this plan, Mr. Whalen recently announced the appointment of Dr. Gerald Wendt, director of the American Institute of the City of New York, to draw up a plan of encouraging and coordinating scientific displays. Even before the appointment of Dr. Wendt,



MODEL OF THE NEW YORK WORLD'S FAIR

THE PICTURE SHOWS THE CENTRAL THIRD OF THE $1,216\frac{3}{4}$ ACRE SITE, INCLUDING THE MAIN EXHIBIT AREA, THE GOVERNMENT AREA (UPPER LEFT) AND A SEGMENT OF THE AMUSEMENT AREA (UPPER RIGHT). THE MOST CONSPICUOUS STRUCTURES ARE THE 18-STORY PERISPHERE AND 700-FOOT TRYLON AT THE THEME CENTER.

however, much progress had been made in this direction.

Innumerable examples could be cited—as, for example, the building of a model town to demonstrate all that traffic engineers and architects and manufacturers and construction engineers have done to make possible a comfortable and gracious way of living. Or the demonstrations of how new industries grow out of abstract scientific research, as will be done by the Radio Corporation of America in the first exhibit of practical television.

One of the most interesting scientific exhibits, however, will be the one telling of the age-long struggle of science against disease and mortality.

"This is not to be an exhibit for doctors," said Mr. Whalen in announcing a committee of eminent physicians appointed to develop the display. "It is an exhibit, however, in which the medical profession surely will be deeply interested. We want to have the subject of medicine and public health brought to the consciousness of the average man. We want him to realize what is available to him in both knowledge and technique, to appreciate dangers and the means of avoiding them in his home life and elsewhere."

For the first time in any international exposition, a large separate building—now nearing completion—is devoted to medicine and public health. The building is divided into three main chambers of great size—the Hall of Man, the Hall of Medical Science and the Hall of Public Health.

The Hall of Man, its interior cathedral-like in design, is to dominate the building. The sound of a low, measured pulsation permeating this vast chamber will be discovered to be the heartbeat of an imposing 18-foot statue of a man standing at one end of the hall. This model, transparent, yet accurate in every particular, will disclose the intricate workings of every organ with which nature has endowed the adult human body.

THE HALL OF MEDICINE AND PUBLIC HEALTH

THE BUILDING WILL BE LOCATED ON THE THEME PLAZA OF THE FAIR AND WILL COST ABOUT $425,000. AMONG THE EXHIBITS WILL BE MODELS OF VARIOUS PARTS OF THE HUMAN BODY LARGE ENOUGH TO PERMIT VISITORS TO ENTER THEM AND BECOME INTIMATELY ACQUAINTED WITH THEIR MECHANISMS.

Surrounding this giant figure, other transparent models will show the processes of respiration and digestion, the action of eye and ear and brain, the mysteries of growth and reproduction.

In the Hall of Medical Science, a series of lifelike dioramas will tell the whole story of the healing art from its crude

beginnings in imitative magic and the incantations of witchmen. One exhibit will show a marketplace of ancient Babylon or Nineveh, with a sick man carried in by his friends to seek the help of any casual passerby.

Another will show the barber-surgeon of the Middle Ages, with his crude unsterilized instruments, ready to shave the patient, extract a tooth or bleed him, all with equal assurance.

Contrasted with this group will be the entire story of modern hospitalization with a staff of chemists, bacteriologists and biologists, behind the scenes in laboratories, perhaps never seeing the patient, but bringing all the resources of science to accurate diagnosis and treatment. Every step in the process of hospitalization will be shown—admission of the patient, diagnosis, nursing care, the operating room with its extraordinary precautions against infection, convalescence and final discharge of the cured patient.

Equally complete will be the exhibits in the Hall of Public Health, where the story of home and municipal sanitation with kindred topics will be presented in a dramatic fashion that entertains while it educates. Here will be a series of exhibits exploding popular yet harmful superstitions. Even the scientist whose specialized activities lie in other directions may find here much that is as surprizing as it is informative.

Similar exhibits will mark other sections of the fair. In the transportation section, for example, will be exhibits telling in pictorial form the entire story of man's search for rapid, comfortable, safe means of travel. Another will tell the progress of aviation, showing all the scientific steps by which safety in the air has been achieved. This will include a complete demonstration of instrument or "blind" flying, showing the means by which the pilot whose vision is obscured by cloud or mist or snow can take off, navigate and land with little if any more trouble than in clear weather.

In a sense, the construction of the New York World's Fair itself is an almost melodramatic demonstration of scientific achievement.

For two centuries, most of the 1,216½-acre site in Flushing Meadow Park was regarded as a useless tidal marsh. On a part of this marsh had been dumped over a period of many years 50,000,000 cubic yards of ashes and refuse. It seemed a difficult enough undertaking to transform this waste land into a sightly park—to say nothing of creating there a magic city with an average population of 300,000 inhabitants.

The first step was to take borings over the entire site—many of them as deep as 100 feet—to find the exact depth to which piling would have to be driven. This task was completed before the first steps of construction were taken.

The entire surface had to be graded. Almost 7,000,000 yards of ash fill and meadow mat had to be moved and redistributed. Topsoil had to be created from these crude materials by the aid of chemical engineers. All these immense undertakings were achieved.

Now, a year before the opening date of April 30, 1939, more than thirty-five buildings are in an advanced state of construction, seven are completed, thousands of trees up to 50 feet tall have been planted, and construction is well advanced on 17 miles of roads and 34 miles of walks. Approximately $10,000,000 has disappeared below ground in such vital improvements as electric wiring, sewers and drains, water mains and telephone cables.

The total cost of the fair will be approximately $150,000,000. The Federal Government, 37 states and 64 foreign governments have taken steps toward active participation. Total attendance at the fair is expected to be 50,000,000. Average daily attendance is calculated at 250,000, with as many as 800,000 on special occasions.

CORRESPONDENT

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